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(54) **METHODS AND SYSTEMS FOR TREATING A BIFURCATION WITH PROVISIONAL SIDE BRANCH STENTING**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

4,069,825 A 1/1978 Akiyama
4,468,224 A 8/1984 Enzmann et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CN 1441654 A 10/2003
CN 1867374 A 11/2006
(Continued)

OTHER PUBLICATIONS

U.S. Appl. No. 14/621,231, filed Feb. 12, 2015 by Bourang et al. (Unpublished.).
(Continued)

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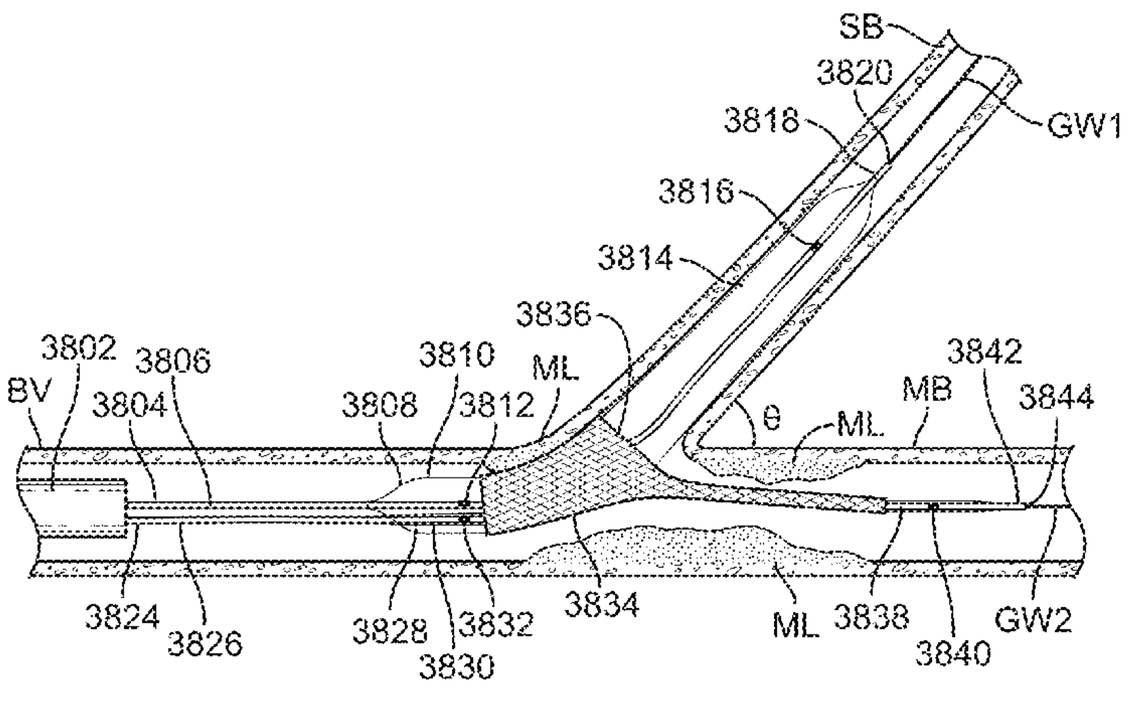
(57) **ABSTRACT**

A system for treating a bifurcation includes first and second delivery catheters, each having an expandable member. A stent having a side hole is disposed on the second delivery catheter. A portion of the first delivery catheter is disposed under a portion of the stent. The first delivery catheter is slidable relative to the second delivery catheter, and the first delivery catheter passes through the side hole. Expansion of the first expandable member expands a portion of the stent and expansion of the second expandable member expands the rest of the stent.

28 Claims, 47 Drawing Sheets



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(56) **References Cited**

U.S. PATENT DOCUMENTS

4,512,338	A	4/1985	Balko
4,564,014	A	1/1986	Fogarty et al.
4,580,568	A	4/1986	Gianturco
4,681,110	A	7/1987	Wiktor
4,690,684	A	9/1987	McGreevy et al.
4,733,665	A	3/1988	Palmaz
4,739,762	A	4/1988	Palmaz
4,762,129	A	8/1988	Bonzel
4,770,176	A	9/1988	McGreevy et al.
4,775,337	A	10/1988	Van Wagener et al.
4,776,337	A	10/1988	Palmaz
4,886,062	A	12/1989	Wiktor
4,891,225	A	1/1990	Langer et al.
4,988,356	A	1/1991	Crittenden et al.
4,994,066	A	2/1991	Voss
4,994,069	A	2/1991	Ritchart et al.
5,013,318	A	5/1991	Spranza, III
5,040,548	A	8/1991	Yock
5,064,435	A	11/1991	Porter
5,092,877	A	3/1992	Pinchuk
5,102,417	A	4/1992	Palmaz
5,104,404	A	4/1992	Wolff
5,122,154	A	6/1992	Rhodes
5,135,535	A	8/1992	Kramer
5,195,984	A	3/1993	Schatz
5,217,495	A	6/1993	Kaplan et al.
5,219,355	A	6/1993	Parodi et al.
5,226,913	A	7/1993	Pinchuk
5,246,421	A	9/1993	Saab
5,273,536	A	12/1993	Savas
5,282,824	A	2/1994	Gianturco
5,300,085	A	4/1994	Yock
5,312,415	A	5/1994	Palermo
5,334,187	A	8/1994	Fischell et al.
5,403,341	A	4/1995	Solar
5,421,955	A	6/1995	Lau et al.
5,456,694	A	10/1995	Marin et al.
5,456,713	A	10/1995	Chuter
5,458,615	A	10/1995	Klemm et al.
5,478,349	A	12/1995	Nicholas
5,490,837	A	2/1996	Blaeser et al.
5,496,346	A	3/1996	Horzewski et al.
5,501,227	A	3/1996	Yock
5,507,768	A	4/1996	Lau et al.
5,507,771	A	4/1996	Gianturco
5,514,093	A	5/1996	Ellis et al.
5,514,154	A	5/1996	Lau et al.
5,527,354	A	6/1996	Fontaine et al.
5,549,551	A	8/1996	Peacock, III et al.
5,549,563	A	8/1996	Kronner
5,549,635	A	8/1996	Solar
5,554,181	A	9/1996	Das
5,562,725	A	10/1996	Schmitt et al.
5,571,086	A	11/1996	Kaplan et al.
5,593,412	A	1/1997	Martinez et al.
5,607,444	A	3/1997	Lam
5,607,463	A	3/1997	Schwartz et al.
5,609,627	A	3/1997	Goicoechea et al.
5,628,775	A	5/1997	Jackson et al.
5,632,763	A	5/1997	Glastra
5,632,772	A	5/1997	Alcime et al.
5,634,928	A	6/1997	Fischell et al.
5,639,274	A	6/1997	Fischell et al.
5,662,675	A	9/1997	Polanskyj Stockert et al.
5,669,924	A	9/1997	Shaknovich
5,670,161	A	9/1997	Healy et al.
5,676,654	A	10/1997	Ellis et al.
5,683,451	A	11/1997	Lenker et al.
5,697,948	A	12/1997	Marin et al.
5,697,967	A	12/1997	Dinh et al.
5,702,418	A	12/1997	Ravenscroft
5,709,701	A	1/1998	Parodi
5,716,393	A	2/1998	Lindenberg et al.
5,722,669	A	3/1998	Shimizu et al.
5,723,003	A	3/1998	Winston et al.
5,735,869	A	4/1998	Fernandez-Aceytuno
5,741,323	A	4/1998	Pathak et al.
5,749,848	A	5/1998	Jang et al.
5,749,921	A	5/1998	Lenker et al.
5,755,735	A	5/1998	Richter et al.
5,755,771	A	5/1998	Penn et al.
5,755,772	A	5/1998	Evans et al.
5,755,776	A	5/1998	Al-Saadon
5,755,781	A	5/1998	Jayaraman
5,769,882	A	6/1998	Fogarty et al.
5,772,669	A	6/1998	Vrba
5,776,141	A	7/1998	Klein et al.
5,797,951	A	8/1998	Mueller et al.
5,800,519	A	9/1998	Sandock
5,807,398	A	9/1998	Shaknovich
5,824,040	A	10/1998	Cox et al.
5,824,041	A	10/1998	Lenker et al.
5,827,320	A	10/1998	Richter et al.
5,833,694	A	11/1998	Poncet
5,836,964	A	11/1998	Richter et al.
5,843,092	A	12/1998	Heller et al.
5,855,563	A	1/1999	Kaplan et al.
5,858,556	A	1/1999	Eckert et al.
5,870,381	A	2/1999	Kawasaki et al.
5,879,370	A	3/1999	Fischell et al.
5,891,190	A	4/1999	Boneau
5,893,887	A	4/1999	Jayaraman
5,895,398	A	4/1999	Wensel et al.
5,899,935	A	5/1999	Ding
5,902,332	A	5/1999	Schatz
5,911,754	A	6/1999	Kanesaka et al.
5,919,175	A	7/1999	Sirhan
5,922,020	A	7/1999	Klein et al.
5,961,536	A	10/1999	Mickley et al.
5,968,069	A	10/1999	Dusbabek et al.
5,972,027	A	10/1999	Johnson
5,976,107	A	11/1999	Mertens et al.
5,976,155	A	11/1999	Foreman et al.
5,980,484	A	11/1999	Ressemann et al.
5,980,486	A	11/1999	Enger
5,980,514	A	11/1999	Kupiecki et al.
5,980,552	A	11/1999	Pinchasik et al.
5,984,957	A	11/1999	Laptewicz, Jr. et al.
5,997,563	A	12/1999	Kretzers et al.
6,004,328	A	12/1999	Solar
6,007,517	A	12/1999	Anderson
6,017,363	A	1/2000	Hojeibane
6,022,359	A	2/2000	Frantzen
6,022,374	A	2/2000	Imran
6,033,434	A	3/2000	Borghi
6,036,725	A	3/2000	Avellanet

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,039,721	A	3/2000	Johnson et al.
6,042,589	A	3/2000	Marianne
6,048,361	A	4/2000	Oepen
6,056,722	A	5/2000	Jayaraman
6,056,775	A	5/2000	Borghi et al.
6,059,811	A	5/2000	Pinchasik et al.
6,059,824	A	5/2000	Taheri
6,066,155	A	5/2000	Amann et al.
6,068,655	A	5/2000	Seguin et al.
6,070,589	A	6/2000	Keith et al.
6,086,604	A	7/2000	Fischell et al.
6,090,063	A	7/2000	Makower et al.
6,090,136	A	7/2000	McDonald et al.
6,096,071	A	8/2000	Yadav
6,096,073	A	8/2000	Webster et al.
6,099,497	A	8/2000	Adams et al.
6,102,942	A	8/2000	Ahari
6,106,530	A	8/2000	Harada
RE36,857	E	9/2000	Euteneuer et al.
6,117,117	A	9/2000	Mauch
6,120,522	A	9/2000	Vrba et al.
6,123,712	A	9/2000	Di Caprio et al.
6,123,723	A	9/2000	Konya et al.
6,126,685	A	10/2000	Lenker et al.
6,129,738	A	10/2000	Lashinski et al.
6,129,756	A	10/2000	Kugler
6,132,460	A	10/2000	Thompson
6,142,973	A	11/2000	Carleton et al.
6,143,016	A	11/2000	Bleam et al.
6,165,167	A	12/2000	Delaloye
6,165,210	A	12/2000	Lau et al.
6,179,878	B1	1/2001	Duerig
6,183,509	B1	2/2001	Dibie
6,187,034	B1	2/2001	Frantzen
6,190,402	B1	2/2001	Horton et al.
6,196,995	B1	3/2001	Fagan
6,200,337	B1	3/2001	Moriuchi et al.
6,210,429	B1	4/2001	Vardi et al.
6,238,991	B1	5/2001	Suzuki
6,241,691	B1	6/2001	Ferrera et al.
6,251,132	B1	6/2001	Ravenscroft et al.
6,251,134	B1	6/2001	Alt et al.
6,254,612	B1	7/2001	Hieshima
6,254,628	B1	7/2001	Wallace et al.
6,258,117	B1	7/2001	Camrud et al.
6,264,682	B1	7/2001	Wilson et al.
6,264,688	B1	7/2001	Herklotz et al.
6,267,783	B1	7/2001	Letendre et al.
6,273,895	B1	8/2001	Pinchuk et al.
6,273,911	B1	8/2001	Cox et al.
6,273,913	B1	8/2001	Wright et al.
6,312,458	B1	11/2001	Golds
6,315,794	B1	11/2001	Richter
6,319,277	B1	11/2001	Rudnick et al.
6,322,586	B1	11/2001	Monroe et al.
6,325,823	B1	12/2001	Horzewski et al.
6,325,826	B1	12/2001	Vardi et al.
6,334,871	B1	1/2002	Dor et al.
6,344,053	B1	2/2002	Boneau
6,344,056	B1	2/2002	Dehdashtian
6,344,272	B1	2/2002	Oldenburg et al.
6,357,104	B1	3/2002	Myers
6,361,555	B1	3/2002	Wilson
6,375,676	B1	4/2002	Cox
6,379,365	B1	4/2002	Diaz
6,383,171	B1	5/2002	Gifford et al.
6,398,807	B1	6/2002	Chouinard et al.
6,409,753	B1	6/2002	Brown et al.
6,415,696	B1	7/2002	Erickson et al.
6,419,693	B1	7/2002	Fariabi
6,428,811	B1	8/2002	West et al.
6,443,982	B1	9/2002	Israel et al.
6,451,025	B1	9/2002	Jervis
6,451,050	B1	9/2002	Rudakov et al.
6,464,720	B2	10/2002	Boatman et al.
6,468,298	B1	10/2002	Pelton
6,468,299	B2	10/2002	Stack et al.
6,485,510	B1	11/2002	Camrud et al.
6,485,511	B2	11/2002	Lau et al.
6,488,694	B1	12/2002	Lau et al.
6,488,702	B1	12/2002	Besselink
6,488,703	B1	12/2002	Kveen et al.
6,511,468	B1	1/2003	Cragg et al.
6,514,281	B1	2/2003	Blaeser et al.
6,520,986	B2	2/2003	Martin et al.
6,520,987	B1	2/2003	Plante
6,520,988	B1	2/2003	Colombo et al.
6,527,789	B1	3/2003	Lau et al.
6,527,799	B2	3/2003	Shanley
6,530,944	B2	3/2003	West et al.
6,540,777	B2	4/2003	Stenzel
6,540,779	B2	4/2003	Richter et al.
6,551,350	B1	4/2003	Thornton et al.
6,555,157	B1	4/2003	Hossainy
6,569,180	B1	5/2003	Sirhan et al.
6,575,993	B1	6/2003	Yock
6,579,305	B1	6/2003	Lashinski
6,579,309	B1	6/2003	Loos et al.
6,582,394	B1	6/2003	Reiss et al.
6,582,460	B1	6/2003	Cryer
6,585,756	B1	7/2003	Strecker
6,592,549	B2	7/2003	Gerdts et al.
6,596,020	B2	7/2003	Vardi et al.
6,596,022	B2	7/2003	Lau et al.
6,599,296	B1	7/2003	Gillick et al.
6,599,314	B2	7/2003	Mathis
6,602,282	B1	8/2003	Yan
6,605,062	B1	8/2003	Hurley et al.
6,605,109	B2	8/2003	Fiedler
6,607,553	B1	8/2003	Healy et al.
6,645,517	B2	11/2003	West
6,645,547	B1	11/2003	Shekalim et al.
6,656,212	B2	12/2003	Ravenscroft et al.
6,660,031	B2	12/2003	Tran et al.
6,660,381	B2	12/2003	Halas et al.
6,666,883	B1	12/2003	Seguin et al.
6,676,695	B2	1/2004	Solem
6,679,909	B2	1/2004	McIntosh et al.
6,685,721	B1	2/2004	Kramer
6,685,730	B2	2/2004	West et al.
6,689,156	B1	2/2004	Davidson et al.
6,692,465	B2	2/2004	Kramer
6,692,483	B2	2/2004	Vardi et al.
6,699,280	B2	3/2004	Camrud et al.
6,699,724	B1	3/2004	West et al.
6,702,843	B1	3/2004	Brown
6,706,062	B2	3/2004	Vardi et al.
6,709,379	B1	3/2004	Brandau et al.
6,709,440	B2	3/2004	Callol et al.
6,712,827	B2	3/2004	Ellis et al.
6,712,845	B2	3/2004	Hossainy
6,723,071	B2	4/2004	Gerdts et al.
6,736,842	B2	5/2004	Healy et al.
6,743,251	B1	6/2004	Eder
6,749,628	B1	6/2004	Cho et al.
6,761,734	B2	7/2004	Suhr
6,770,091	B2	8/2004	Richter et al.
6,778,316	B2	8/2004	Halas et al.
6,800,065	B2	10/2004	Duane et al.
6,811,566	B1	11/2004	Penn et al.
6,825,203	B2	11/2004	Pasternak et al.
6,835,203	B1	12/2004	Vardi et al.
6,837,901	B2	1/2005	Rabkin et al.
6,849,084	B2	2/2005	Rabkin et al.
6,852,252	B2	2/2005	Halas et al.
6,855,125	B2	2/2005	Shanley
6,858,034	B1	2/2005	Hijlkema et al.
6,875,228	B2	4/2005	Pinchasik et al.
6,878,161	B2	4/2005	Lenker
6,879,370	B2	4/2005	Yokoue et al.
6,884,258	B2	4/2005	Vardi et al.
6,893,417	B2	5/2005	Gribbons et al.
6,896,695	B2	5/2005	Mueller et al.
6,908,477	B2	6/2005	McGuckin, Jr. et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,918,928	B2	7/2005	Wolinsky et al.
6,939,376	B2	9/2005	Shulz et al.
6,945,989	B1	9/2005	Betelia et al.
6,945,995	B2	9/2005	Nicholas
6,949,120	B2	9/2005	Kveen et al.
6,951,053	B2	10/2005	Padilla et al.
6,955,687	B2	10/2005	Richter et al.
6,955,688	B2	10/2005	Wilson et al.
6,962,602	B2	11/2005	Vardi et al.
6,989,026	B2	1/2006	Richter et al.
7,005,454	B2	2/2006	Brocchini et al.
7,037,327	B2	5/2006	Salmon et al.
7,090,694	B1	8/2006	Morris et al.
7,101,840	B2	9/2006	Brocchini et al.
7,137,993	B2	11/2006	Acosta et al.
7,147,655	B2	12/2006	Chermoni
7,147,656	B2	12/2006	Andreas et al.
7,182,779	B2	2/2007	Acosta et al.
7,192,440	B2	3/2007	Andreas et al.
7,220,275	B2	5/2007	Davidson et al.
7,241,308	B2	7/2007	Andreas et al.
7,270,668	B2	9/2007	Andreas et al.
7,294,146	B2	11/2007	Chew et al.
7,300,456	B2	11/2007	Andreas et al.
7,309,350	B2	12/2007	Landreville et al.
7,314,480	B2	1/2008	Eidenschink et al.
7,320,702	B2	1/2008	Hammersmark et al.
7,323,006	B2	1/2008	Andreas et al.
7,323,009	B2	1/2008	Suhr et al.
7,326,236	B2	2/2008	Andreas et al.
7,326,242	B2	2/2008	Eidenschink
7,341,598	B2	3/2008	Davidson et al.
7,387,639	B2	6/2008	Bourang et al.
7,445,688	B2	11/2008	Suzuki et al.
7,520,895	B2	4/2009	Douglas et al.
7,537,609	B2	5/2009	Davidson et al.
7,540,881	B2	6/2009	Meyer et al.
7,635,383	B2	12/2009	Gumm
7,641,684	B2	1/2010	Hillaire et al.
7,641,685	B2	1/2010	Richter
7,695,508	B2	4/2010	Der Leest et al.
8,016,870	B2	9/2011	Chew et al.
8,070,789	B2	12/2011	Will et al.
8,769,796	B2	7/2014	Bourang et al.
8,795,347	B2	8/2014	Bourang et al.
8,808,347	B2	8/2014	Bourang et al.
8,821,562	B2	9/2014	Bourang et al.
8,828,071	B2	9/2014	Bourang et al.
8,979,917	B2	3/2015	Bourang et al.
2001/0003161	A1	6/2001	Vardi et al.
2001/0020154	A1	9/2001	Bigus et al.
2001/0020181	A1	9/2001	Layne
2001/0044595	A1	11/2001	Reydel et al.
2001/0044622	A1	11/2001	Vardi et al.
2001/0044632	A1	11/2001	Daniel et al.
2001/0049547	A1	12/2001	Moore
2002/0037358	A1	3/2002	Barry et al.
2002/0091439	A1	7/2002	Baker et al.
2002/0107560	A1	8/2002	Richter
2002/0111671	A1	8/2002	Stenzel
2002/0128706	A1	9/2002	Ospyka
2002/0138132	A1	9/2002	Brown
2002/0143382	A1	10/2002	Hijlkema et al.
2002/0151924	A1	10/2002	Shiber
2002/0151955	A1	10/2002	Tran et al.
2002/0156496	A1	10/2002	Chermoni
2002/0173835	A1	11/2002	Bourang et al.
2002/0177890	A1	11/2002	Lenker
2002/0183763	A1	12/2002	Callol et al.
2002/0188343	A1	12/2002	Mathis
2002/0188347	A1	12/2002	Mathis
2002/0193873	A1	12/2002	Brucker et al.
2003/0028233	A1	2/2003	Vardi et al.
2003/0029039	A1	2/2003	Richter et al.
2003/0045923	A1	3/2003	Bashiri et al.
2003/0093143	A1	5/2003	Zhao et al.
2003/0097169	A1	5/2003	Brucker et al.
2003/0114912	A1	6/2003	Sequin et al.
2003/0114919	A1	6/2003	McQuiston et al.
2003/0114922	A1	6/2003	Iwasaka et al.
2003/0125791	A1	7/2003	Sequin et al.
2003/0125800	A1	7/2003	Shulze et al.
2003/0125802	A1	7/2003	Callol et al.
2003/0135259	A1	7/2003	Simso
2003/0135266	A1	7/2003	Chew et al.
2003/0139796	A1	7/2003	Sequin et al.
2003/0139797	A1	7/2003	Johnson et al.
2003/0139798	A1	7/2003	Brown et al.
2003/0163085	A1	8/2003	Tanner et al.
2003/0176909	A1	9/2003	Kusleika
2003/0191516	A1	10/2003	Weldon et al.
2003/0192164	A1	10/2003	Austin
2003/0195609	A1	10/2003	Berenstein
2003/0199821	A1	10/2003	Gerdts et al.
2003/0204238	A1	10/2003	Tedeschi
2003/0212447	A1	11/2003	Euteneuer
2003/0225446	A1	12/2003	Hartley
2004/0024450	A1	2/2004	Shulze et al.
2004/0030380	A1	2/2004	Shulze et al.
2004/0044395	A1	3/2004	Nelson
2004/0044398	A1	3/2004	Nicholas
2004/0087965	A1	5/2004	Levine et al.
2004/0093061	A1	5/2004	Acosta et al.
2004/0093067	A1	5/2004	Israel
2004/0093077	A1	5/2004	White et al.
2004/0098081	A1	5/2004	Landreville et al.
2004/0106979	A1	6/2004	Goicoechea
2004/0111145	A1	6/2004	Serino et al.
2004/0117008	A1	6/2004	Wnendt et al.
2004/0176832	A1	9/2004	Hartley et al.
2004/0186551	A1	9/2004	Kao et al.
2004/0193245	A1	9/2004	Deem et al.
2004/0215165	A1	10/2004	Coyle et al.
2004/0215312	A1	10/2004	Andreas et al.
2004/0243217	A1	12/2004	Andersen et al.
2004/0249434	A1	12/2004	Andreas et al.
2004/0249435	A1	12/2004	Andreas et al.
2005/0010276	A1	1/2005	Acosta et al.
2005/0038505	A1	2/2005	Shuize et al.
2005/0049673	A1	3/2005	Andreas et al.
2005/0049680	A1	3/2005	Fischell et al.
2005/0080474	A1	4/2005	Andreas et al.
2005/0080475	A1	4/2005	Andreas et al.
2005/0085845	A1	4/2005	Hilaire et al.
2005/0090846	A1	4/2005	Pedersen et al.
2005/0101624	A1	5/2005	Betts et al.
2005/0125051	A1	6/2005	Eidenschink et al.
2005/0131008	A1	6/2005	Betts et al.
2005/0133164	A1	6/2005	Fischer et al.
2005/0143827	A1	6/2005	Globerman et al.
2005/0149159	A1	7/2005	Andreas et al.
2005/0165378	A1	7/2005	Heinrich et al.
2005/0182473	A1	8/2005	Eidenschink et al.
2005/0183259	A1	8/2005	Eidenschink et al.
2005/0197688	A1	9/2005	Theron et al.
2005/0209674	A1	9/2005	Kutscher et al.
2005/0222671	A1	10/2005	Schaeffer et al.
2005/0228477	A1	10/2005	Grainger et al.
2005/0245637	A1	11/2005	Hossainy et al.
2005/0288763	A1	12/2005	Andreas et al.
2005/0288764	A1	12/2005	Snow et al.
2005/0288766	A1	12/2005	Plain et al.
2006/0069424	A1	3/2006	Acosta et al.
2006/0100694	A1	5/2006	Globerman
2006/0123874	A1	6/2006	Motsenbocker
2006/0200223	A1	9/2006	Andreas et al.
2006/0206190	A1	9/2006	Chermoni
2006/0229700	A1	10/2006	Acosta et al.
2006/0229706	A1	10/2006	Shulze et al.
2006/0271090	A1	11/2006	Shaked et al.
2006/0271150	A1	11/2006	Andreas et al.
2006/0271151	A1	11/2006	McGarry et al.
2006/0282147	A1	12/2006	Andreas et al.
2006/0282149	A1	12/2006	Kao

(56) **References Cited**

U.S. PATENT DOCUMENTS

2006/0282150	A1	12/2006	Olson et al.
2006/0287726	A1	12/2006	Segal et al.
2007/0027521	A1	2/2007	Andreas et al.
2007/0027524	A1	2/2007	Johnson et al.
2007/0055351	A1	3/2007	Eidenschink et al.
2007/0061003	A1	3/2007	Shmulewitz et al.
2007/0067012	A1	3/2007	George et al.
2007/0088368	A1	4/2007	Acosta et al.
2007/0088420	A1	4/2007	Andreas et al.
2007/0088422	A1	4/2007	Chew et al.
2007/0100423	A1	5/2007	Acosta et al.
2007/0100424	A1	5/2007	Chew et al.
2007/0106365	A1	5/2007	Andreas et al.
2007/0118202	A1	5/2007	Chermoni
2007/0118203	A1	5/2007	Chermoni
2007/0118204	A1	5/2007	Chermoni
2007/0129733	A1	6/2007	Will et al.
2007/0156225	A1	7/2007	George et al.
2007/0156226	A1	7/2007	Chew et al.
2007/0179587	A1	8/2007	Acosta et al.
2007/0203571	A1	8/2007	Kaplan et al.
2007/0219611	A1	9/2007	Krever et al.
2007/0219612	A1	9/2007	Andreas et al.
2007/0219613	A1	9/2007	Kao et al.
2007/0219625	A1	9/2007	Venturelli et al.
2007/0265637	A1	11/2007	Andreas et al.
2007/0270936	A1	11/2007	Andreas et al.
2007/0276460	A1	11/2007	Davis et al.
2007/0276461	A1	11/2007	Andreas et al.
2007/0281117	A1	12/2007	Kaplan et al.
2007/0282419	A1	12/2007	Hilaire et al.
2007/0292518	A1	12/2007	Ludwig
2008/0009932	A1	1/2008	Ta et al.
2008/0009933	A1	1/2008	Ta et al.
2008/0051869	A1	2/2008	Yribarren
2008/0071345	A1	3/2008	Hammersmark et al.
2008/0077229	A1	3/2008	Andreas et al.
2008/0091257	A1	4/2008	Andreas et al.
2008/0097299	A1	4/2008	Andreas et al.
2008/0097574	A1	4/2008	Andreas et al.
2008/0132989	A1	6/2008	Snow et al.
2008/0147162	A1	6/2008	Andreas et al.
2008/0199510	A1	8/2008	Ruane et al.
2008/0208309	A1	8/2008	Saeed
2008/0208311	A1	8/2008	Kao et al.
2008/0208318	A1	8/2008	Kao et al.
2008/0221655	A1	9/2008	Miller
2008/0234795	A1	9/2008	Snow et al.
2008/0234798	A1	9/2008	Chew et al.
2008/0234799	A1	9/2008	Acosta et al.
2008/0269865	A1	10/2008	Snow et al.
2009/0076584	A1	3/2009	Mao et al.
2009/0105686	A1	4/2009	Snow et al.
2009/0132019	A1	5/2009	Duffy et al.
2009/0143854	A1	6/2009	Adams et al.
2009/0171430	A1	7/2009	Baim et al.
2009/0182270	A1	7/2009	Nanavati
2009/0228088	A1	9/2009	Lowe et al.
2009/0240321	A1	9/2009	Davidson et al.
2009/0254167	A1	10/2009	Ricci et al.
2009/0259285	A1	10/2009	Duane et al.
2009/0287289	A1	11/2009	Sagedahl et al.
2009/0299454	A1	12/2009	Jennings et al.
2009/0319030	A1	12/2009	Yadin et al.
2009/0326641	A1	12/2009	Davis et al.
2010/0004737	A1	1/2010	Eidenschink
2010/0030183	A1	2/2010	Toner et al.
2010/0036477	A1	2/2010	Bronson et al.
2010/0042199	A1	2/2010	Burton
2010/0049298	A1	2/2010	Hamer et al.
2010/0057020	A1	3/2010	Uretsky
2010/0063571	A1	3/2010	Roach et al.
2010/0106238	A1	4/2010	Hillaire et al.
2011/0029061	A1	2/2011	Ahn et al.
2011/0307047	A1	12/2011	Bourang et al.
2013/0268047	A1	10/2013	Bourang
2014/0100647	A1	4/2014	Bourang
2015/0032196	A1	1/2015	Bourang et al.

FOREIGN PATENT DOCUMENTS

CN	101035488	A	12/2007
CN	102215780	A	10/2011
CN	103037813	A	4/2013
CN	103037815	A	4/2013
CN	103037816	A	4/2013
CN	103037817	A	4/2013
CN	103068345	A	4/2013
EP	0 203 945	B2	12/1986
EP	0 274 129	B1	7/1988
EP	0 282 143	A1	9/1988
EP	0 505 686	A1	9/1992
EP	0 533 960	A1	3/1993
EP	0 714 640	A1	6/1996
EP	0 596 145	A1	5/1997
EP	0 897 700	A1	2/1999
EP	0 947180	A2	10/1999
EP	1 258 230	A2	11/2002
EP	1 277 449	A1	1/2003
EP	1 523 959	A2	4/2005
EP	1 523 960	A2	4/2005
EP	1 266 638	A2	10/2005
EP	1 788 977	B1	3/2008
EP	1 905 398	A2	4/2008
EP	2 344 068	A1	7/2011
EP	2 549 949	A1	1/2013
EP	2 549 950	A1	1/2013
EP	2 549 951	A1	1/2013
EP	2 549 952	A1	1/2013
EP	2549958	A1	1/2013
EP	2 672 925		12/2013
EP	2 672 932		12/2013
JP	10-043313		2/1998
JP	2003-532437	A	11/2003
JP	2004-528877	A	9/2004
JP	2007-508082	A	4/2007
JP	2010-503465	A	4/2010
JP	2012-503534	A	2/2012
JP	2013523215	A	6/2013
WO	WO 96/26689	A1	9/1996
WO	WO 96/33677	A2	10/1996
WO	WO 97/46174	A1	12/1997
WO	WO 97/48351	A1	12/1997
WO	WO 98/20810	A1	5/1998
WO	WO 98/37833	A1	9/1998
WO	WO 98/58600	A1	12/1998
WO	WO 99/01087	A1	1/1999
WO	WO 00/12832	A2	3/2000
WO	WO 00/15151	A1	3/2000
WO	WO 00/25841	A1	5/2000
WO	WO 00/32136	A1	6/2000
WO	WO 00/41649	A1	7/2000
WO	WO 00/50116	A1	8/2000
WO	WO 00/62708	A1	10/2000
WO	WO 00/72780	A1	12/2000
WO	WO 00/74595	A1	12/2000
WO	WO 01/70297	A2	9/2001
WO	WO 01/91918	A1	12/2001
WO	WO 02/060344	A2	8/2002
WO	WO 02/085253	A1	10/2002
WO	WO 03/022178	A1	3/2003
WO	WO 03/047651	A2	6/2003
WO	WO 03/051425	A2	6/2003
WO	WO 03/055414	A1	7/2003
WO	WO 03/105922	A2	12/2003
WO	WO 2004/017865	A1	3/2004
WO	WO 2004/043299	A1	5/2004
WO	WO 2004/043301	A1	5/2004
WO	WO 2004/043510	A1	5/2004
WO	WO 2004/052237	A2	6/2004
WO	WO 2005/013853	A2	2/2005
WO	WO 2005/039681	A1	5/2005
WO	WO 2006/036939	A2	4/2006
WO	WO 2006/047520	A2	5/2006

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

WO	WO 2007/035805	A2	3/2007
WO	WO 2007/053187	A2	5/2007
WO	WO 2007/146411	A2	12/2007
WO	WO 2008/005111	A1	1/2008
WO	WO 2008/033621	A1	3/2008
WO	WO 2008/130503	A2	10/2008
WO	WO 2009/148594	A1	12/2009
WO	WO 2010/036982	A1	4/2010
WO	WO 2011/119879	A1	9/2011
WO	WO 2011/119880	A1	9/2011
WO	WO 2011/119882	A1	9/2011
WO	WO 2011/119883	A1	9/2011
WO	WO 2011/119884	A1	9/2011
WO	WO 2012/109365	A1	8/2012
WO	WO 2012/109382	A2	8/2012

OTHER PUBLICATIONS

Patent Examination Report No. 1 for corresponding Australian Patent Application No. 2011232360 dated Dec. 9, 2014, 2 pages.
"Drug Delivery Stent with Holes Located on Neutral Axis"; No. 429007; Research Disclosure, Kenneth Mason Publications, Hampshire, CB; Jan. 2000; pp. 13; vol. 2266.
"Stent". Definitions from Dictionary.com. Unabridged (v1.01). Retrieved Sep. 22, 2006, from Dictionary.com, located at http://dictionary.reference.com/search?q=stent; 1 page.
Colombo, "The Invatec Bifurcation Stent Solution" Bifurcation Stents: Novel Solutions, TCT 2003, Washington: Sep. 15-19, 2003, 24 pages.
Cooley, Patrick et al.; "Applications of Ink-Jet Printing Technology to BioMEMs and Microfluidic Systems"; Proceedings, SPIE Conference on Microfluidics and BioMEMs; Oct. 2001; 12 pages.
Evans Analytical Group; "Functional Sites on Non-polymeric Materials: Gas Plasma Treatment and Surface Analysis"; located at http://www.eaglabs.com;2003; 2 pages.
International Search Report mailed on May 27, 2011, for PCT Patent Application No. PCT/US2011/029863, filed on Mar. 24, 2011, 2 pages.
Joung, Yoon Ki et al.; "Estrogen Release from Metallic Stent Surface for the Prevention of Restenosis"; Journal of Controlled Release; 2003; pp. 83-91; vol. 92.
Lefèvre, Thierry et al. "Approach to Coronary Bifurcation Stenting in 2003"; Euro PCR; May 2003; pp. 127-154.
Stimpson, Donald I. et al; "Parallel Production of Oligonucleotide Arrays Using Membranes and Reagent Jet Printing"; BioTechniques; Nov. 1998; pp. 886-890; vol. 25.
Supplementary European Search Report dated Mar. 25, 2008, for EP Patent Application No. 05727731.1, 2 pages.
Supplementary European Search Report mailed on Apr. 9, 2008, for EP Patent Application No. 05744136.2, 3 pages.
U.S. Appl. No. 09/097,855, filed Jun. 15, 1998, first named inventor: Enrique J. Klein.
U.S. Appl. No. 09/225,364, filed Jan. 4, 1999, first named inventor: Aaron V. Kaplan.
U.S. Appl. No. 10/874,859, filed Jun. 22, 2004, first named inventor: Pablo Acosta.
U.S. Appl. No. 60/336,607, filed Dec. 3, 2001, first named inventor: Bernard Andreas.
U.S. Appl. No. 60/336,767, filed Dec. 3, 2001, first named inventor: Bernard Andreas.
U.S. Appl. No. 60/336,967, filed Dec. 3, 2001, first named inventor: Sunmi Chew.
U.S. Appl. No. 60/364,389, filed Mar. 13, 2002, first named inventor: Sunmi Chew.
U.S. Appl. No. 60/440,839, filed Jan. 17, 2003, first named inventor: Bernard Andreas.
U.S. Appl. No. 60/561,041, filed Apr. 9, 2004, first named inventor: Jeffry Grainger.
U.S. Appl. No. 60/784,309, filed Mar. 20, 2006, first named inventor: Bernard Andreas.
U.S. Appl. No. 60/810,522, filed Jun. 2, 2006, first named inventor: Stephen Kaplan.
U.S. Appl. No. 60/890,703, filed Feb. 20, 2007, first named inventor: Patrick Ruane.
U.S. Appl. No. 61/012,317, filed Dec. 7, 2007, first named inventor: Patrick Ruane.
Written Opinion of the International Searching Authority mailed on May 27, 2011, for PCT Patent Application No. PCT/US2011/029863, filed on Mar. 24, 2011, 11 pages.
First Office Action for corresponding Chinese Application No. 200980143592.X dated Jun. 4, 2013, 10 pages.
International Preliminary Report on Patentability of Application No. PCT/US2009/058505, Oct. 28, 2010, 38 pages.
International Search Report and Written Opinion of Application No. PCT/US2009/058505, Nov. 25, 2009, 11 pages.
International Search Report and Written Opinion of Application No. PCT/US2011/029858, May 25, 2011, 10 pages.
International Preliminary Report on Patentability of Application No. PCT/US2011/029859, Sep. 25, 2012, 8 pages.
International Search Report and Written Opinion of Application No. PCT/US2011/029859, May 23, 2011, 8 pages.
International Preliminary Report on Patentability of Application No. PCT/US2011/029861, Sep. 25, 2012, 9 pages.
International Search Report and Written Opinion of Application No. PCT/US2011/029861, May 20, 2011, 11 pages.
International Preliminary Report on Patentability of Application No. PCT/US2011/029862, Sep. 25, 2012, 11 pages.
International Search Report and Written Opinion of Application No. PCT/US2011/029862, May 25, 2011, 13 pages.
International Preliminary Report on Patentability of Application No. PCT/US2011/029863, Sep. 25, 2012, 13 pages.
International Preliminary Report on Patentability of Application No. PCT/US2012/024347, Aug. 13, 2013, 8 pages.
International Search Report and Written Opinion of Application No. PCT/US2012/024347, Jun. 29, 2012, 13 pages.
International Preliminary Report on Patentability of Application No. PCT/US2012/024366, Aug. 13, 2013, 19 pages.
International Search Report and Written Opinion of Application No. PCT/US2012/024366, Sep. 7, 2012, 23 pages.
Invitation to Pay Additional Fees of Application No. PCT/US2012/024366, Jun. 1, 2012, 3 pages.
Office Action for corresponding Japanese Patent Application No. 2011-529290, mailed Sep. 25, 2013, 5 pages.
English Translation and Second Office Action for corresponding Chinese Patent Application No. 200980143592.X dated Apr. 21, 2014, 26 pages.
Notice of Allowance for U.S. Appl. No. 13/071,198 mailed on Mar. 24, 2014, 11 pages.
English Translation and Notice of First Office Action for corresponding Chinese Patent Application No. 201180025716.1 dated Aug. 22, 2014, 28 pages.
U.S. Appl. No. 14/317,387, filed Jun. 27, 2014 by Bourang et al. (Unpublished.).
U.S. Appl. No. 14/294,631, filed Jun. 3, 2014 by Bourang et al. (Unpublished.).
U.S. Appl. No. 14/313,742, filed Jun. 24, 2014 by Bourang et al. (Unpublished.).
U.S. Appl. No. 14/321,506, filed Jul. 1, 2014 by Bourang et al. (Unpublished.).

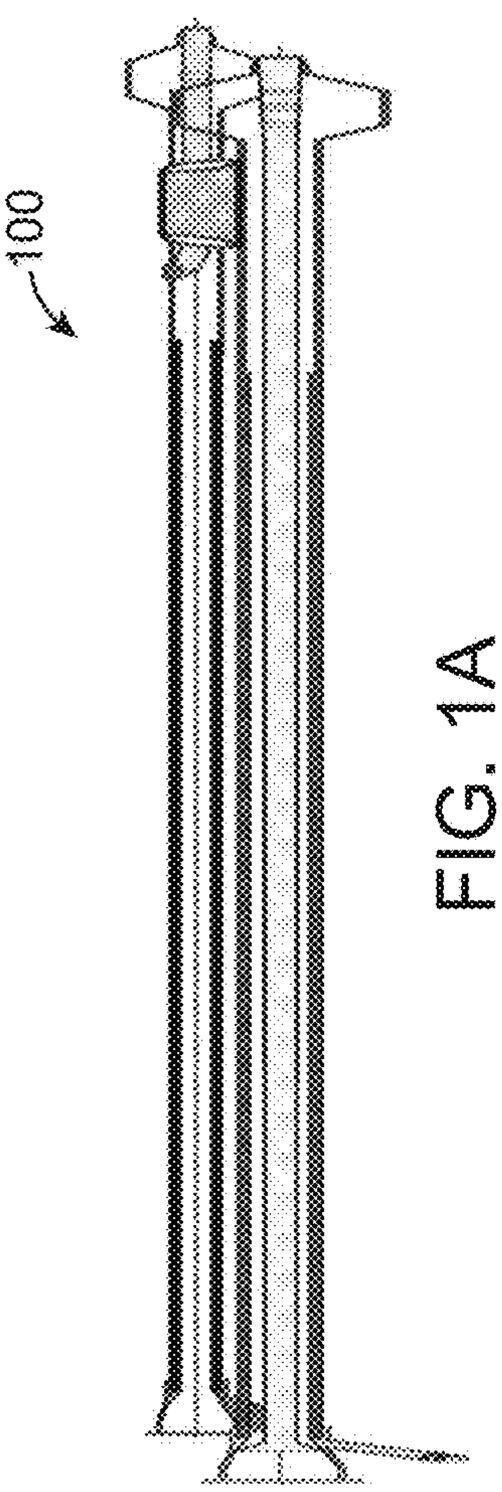
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FIG. 1A

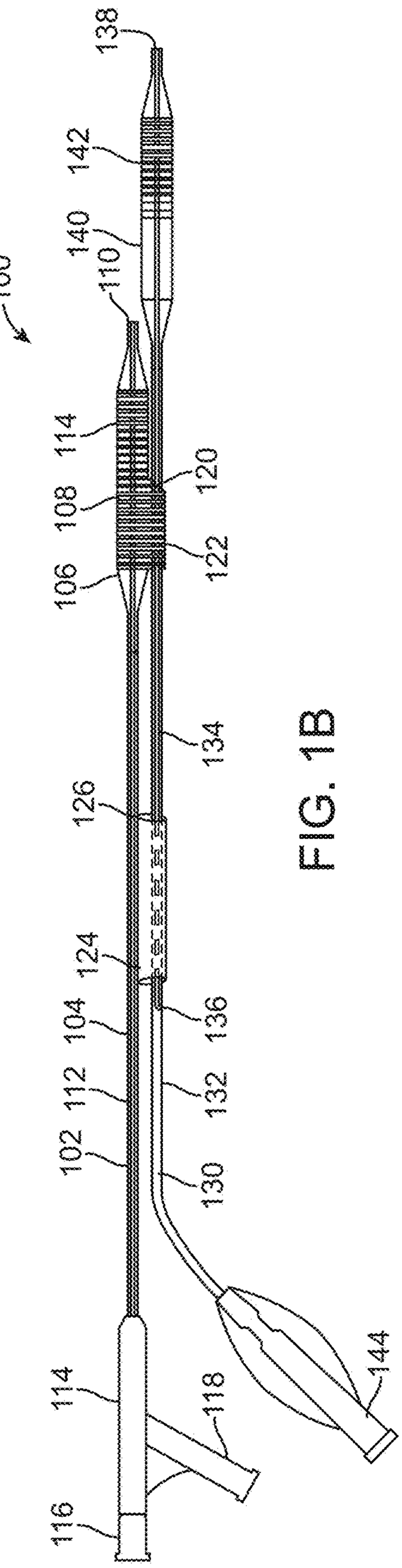
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FIG. 1B

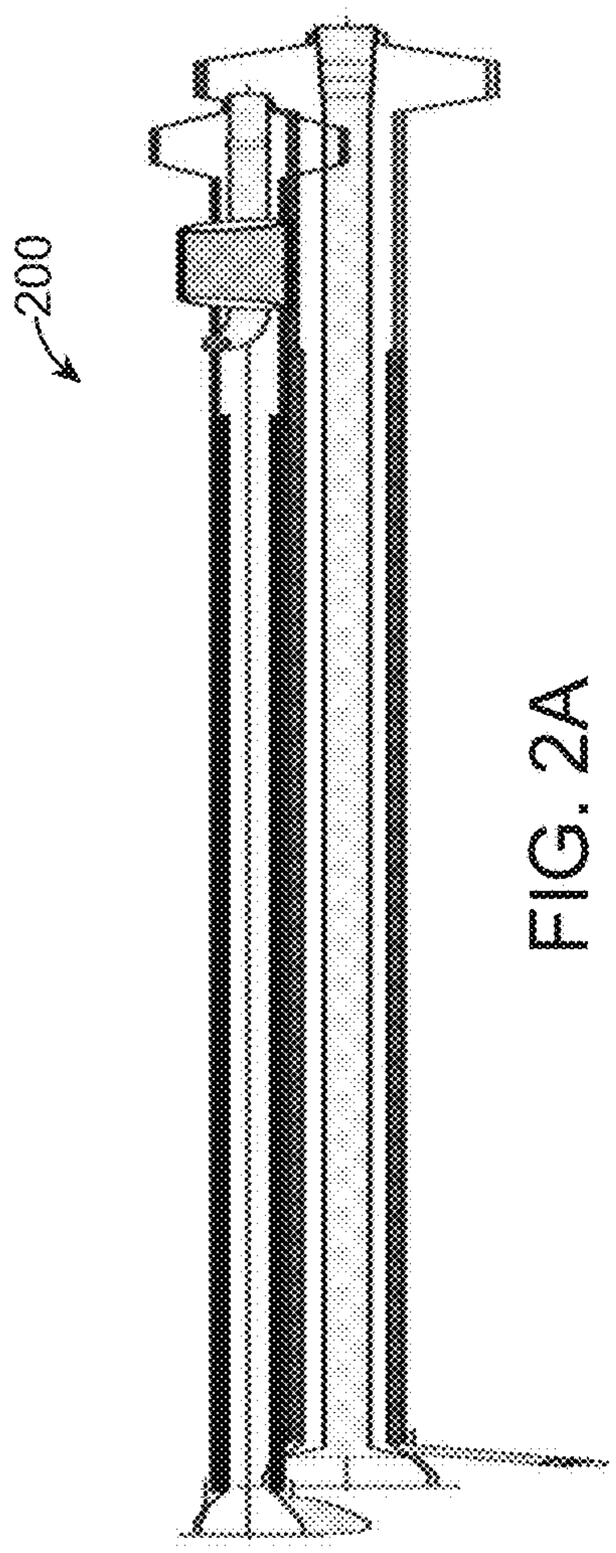
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FIG. 2A

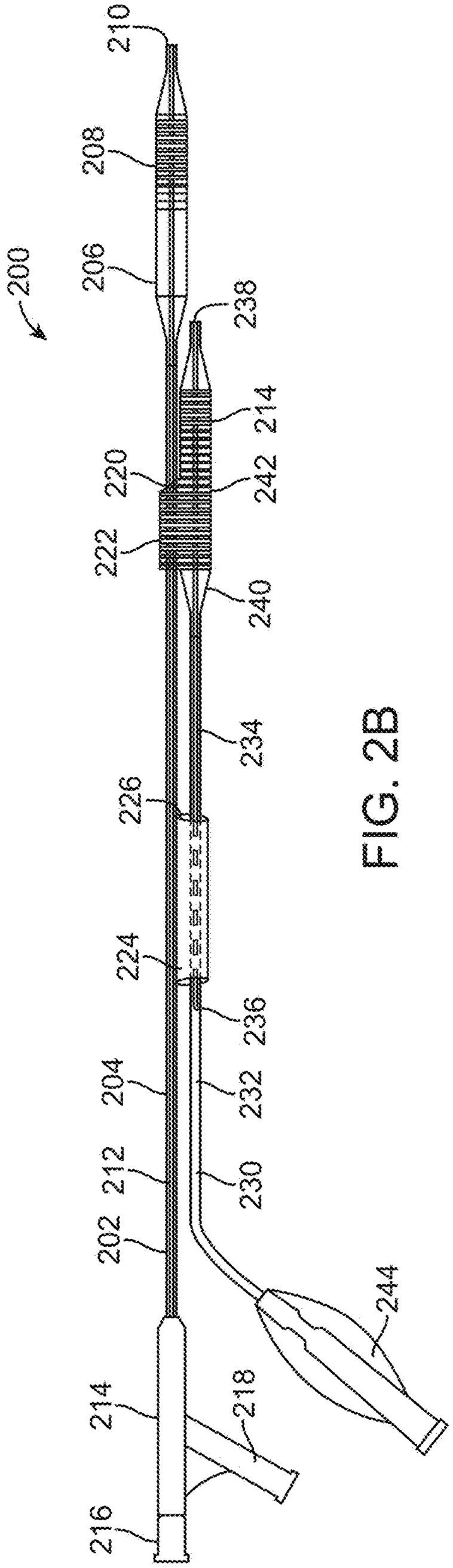
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FIG. 2B

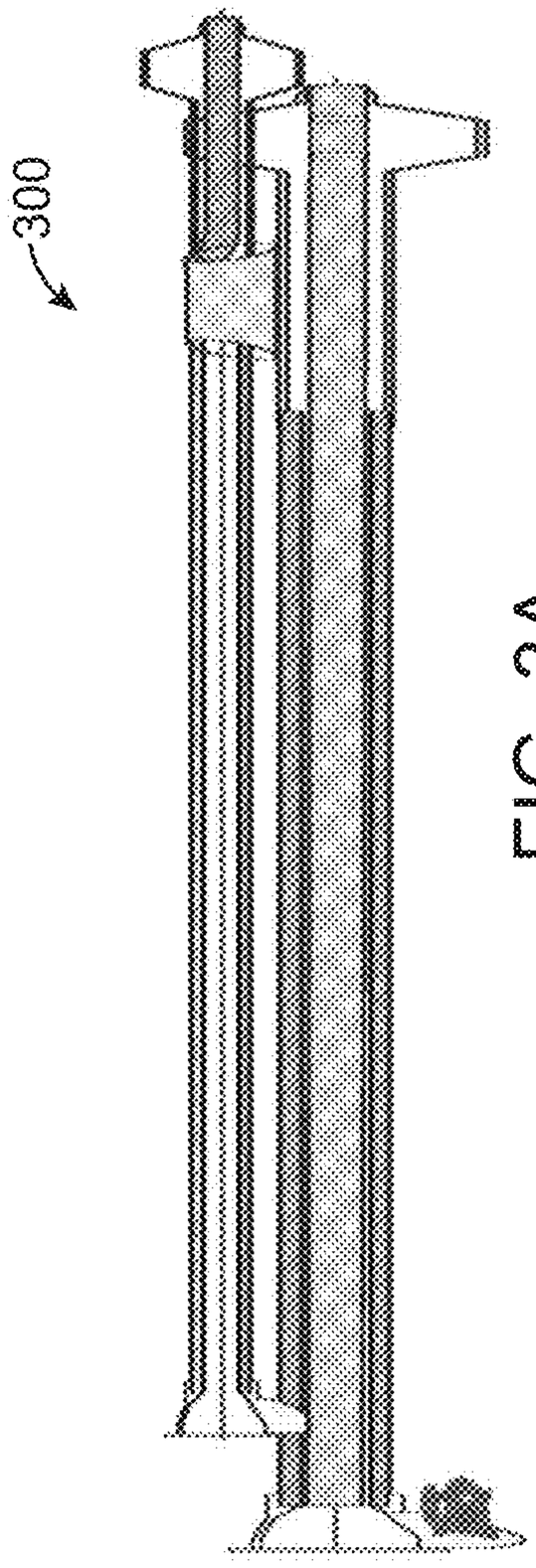
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FIG. 3A

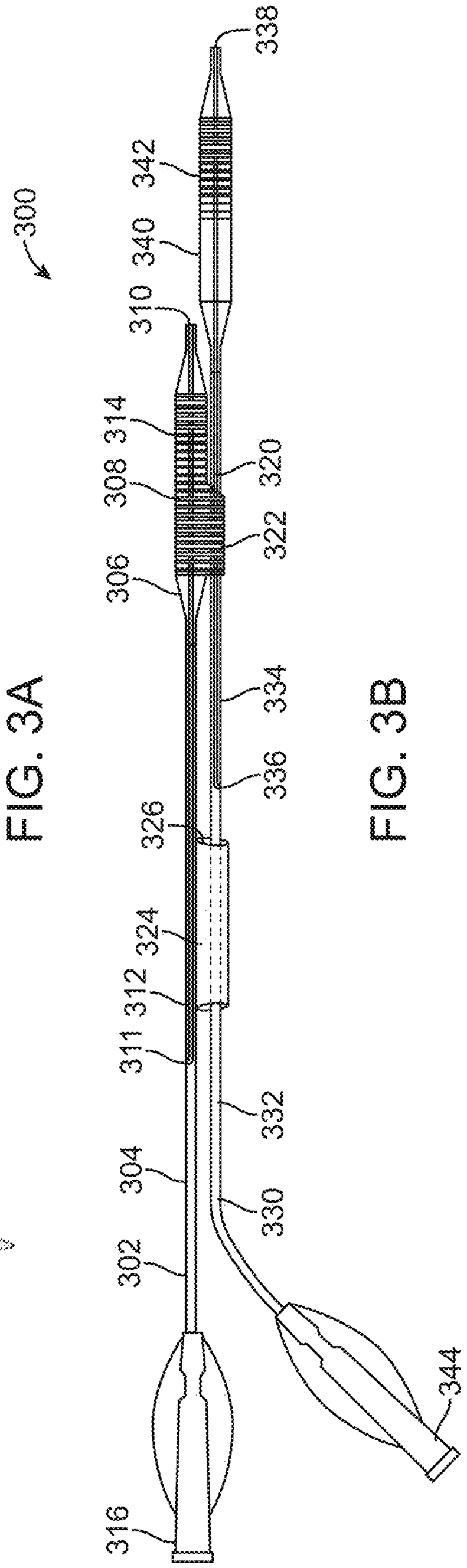
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FIG. 3B

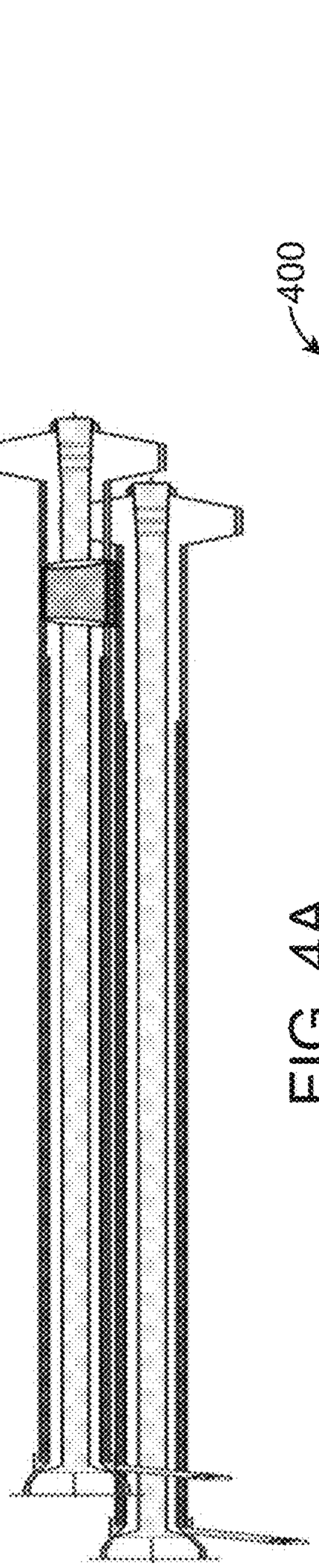
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FIG. 4A

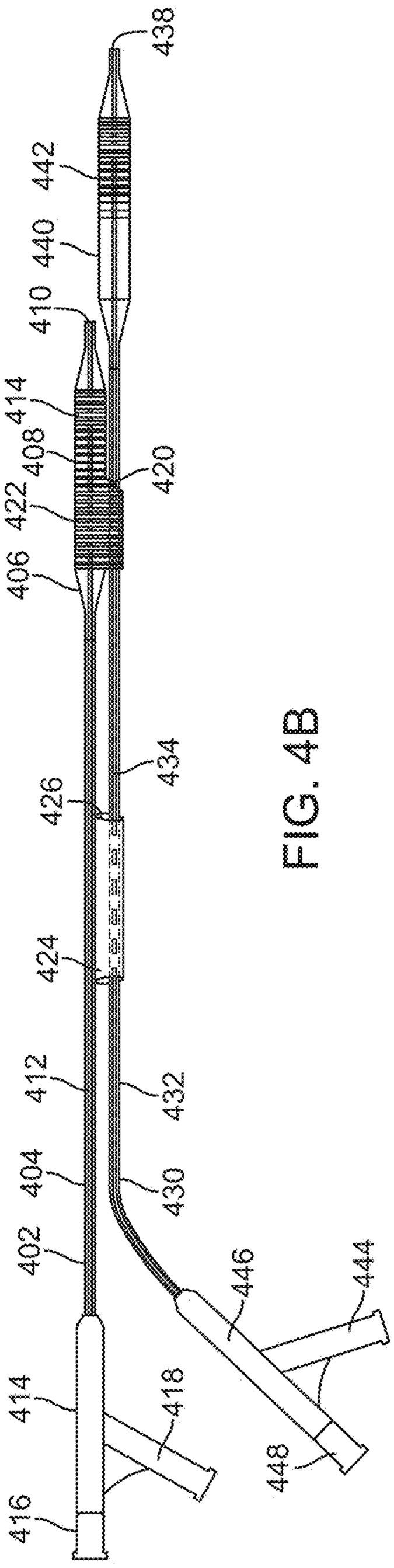
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FIG. 4B

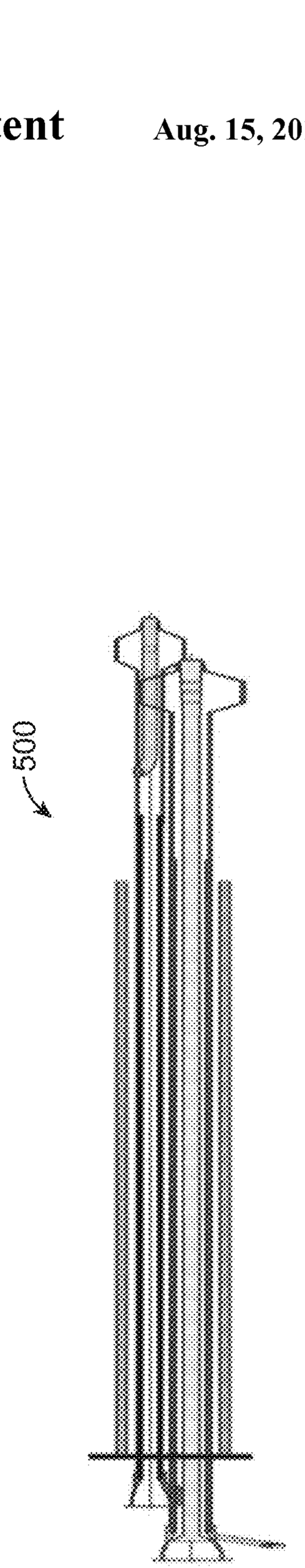
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FIG. 5A

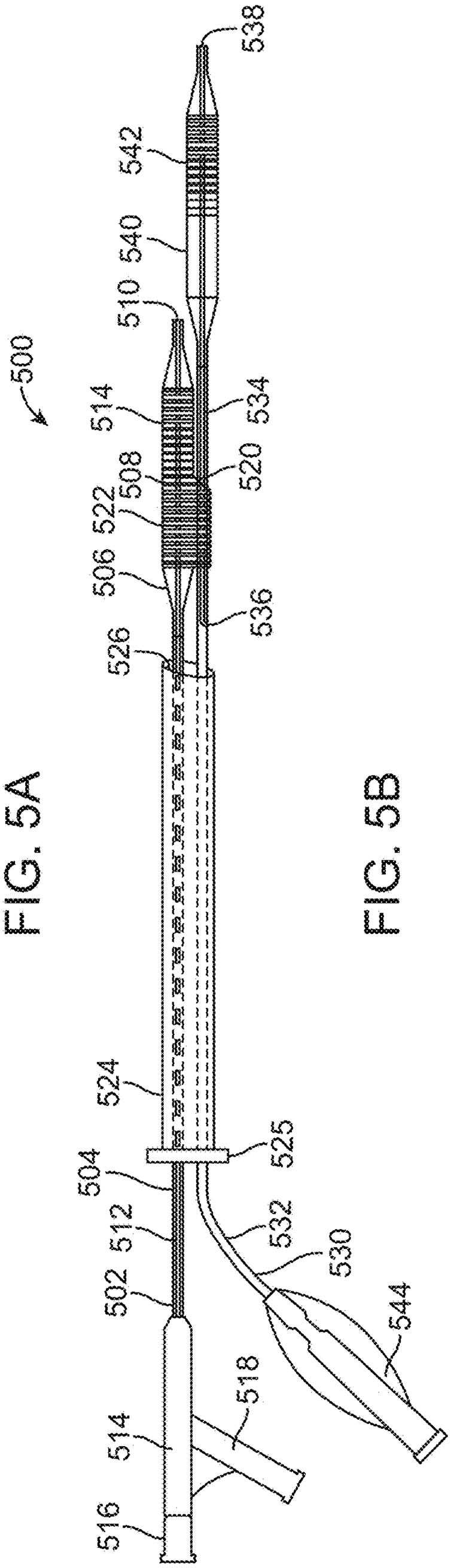
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FIG. 5B

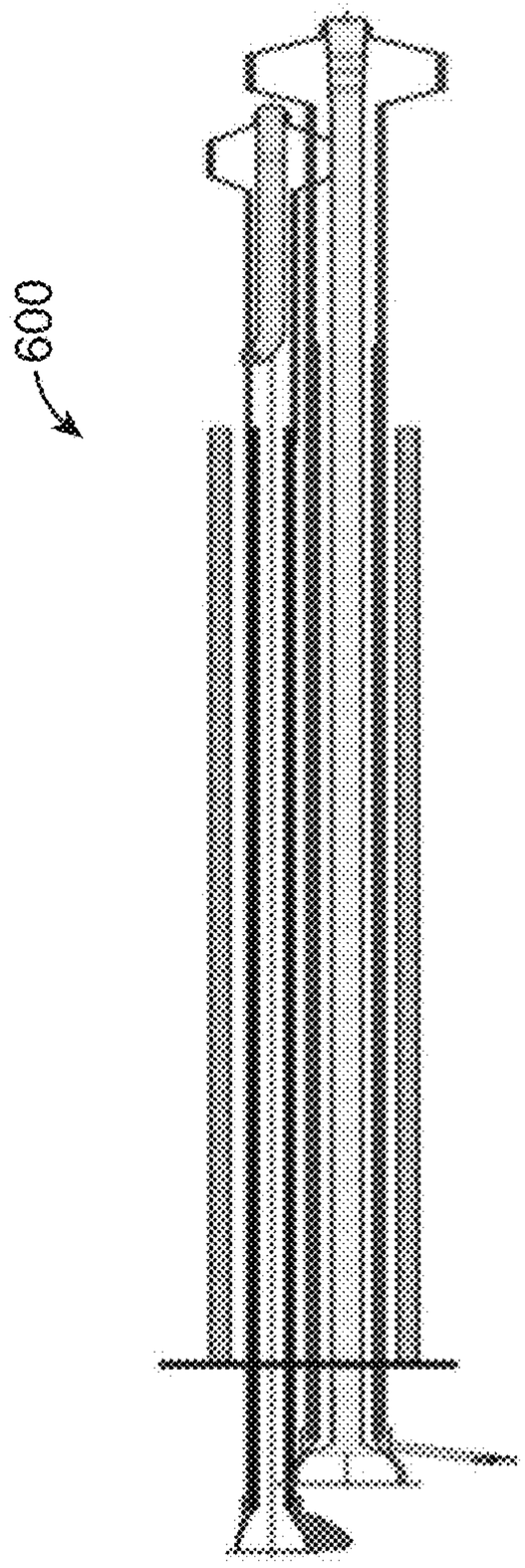
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FIG. 6A

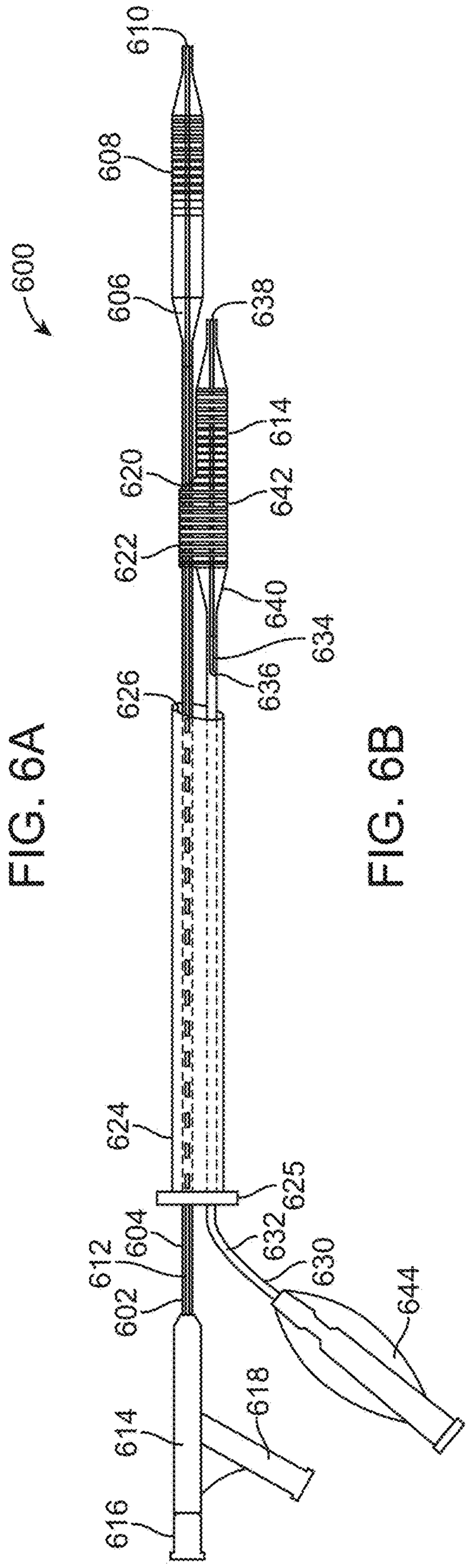
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FIG. 6B

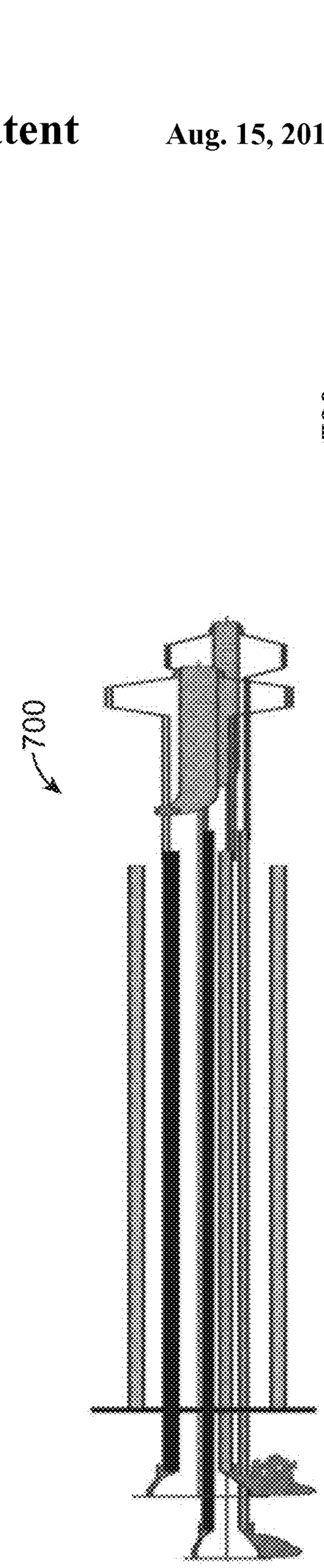
700

FIG. 7A

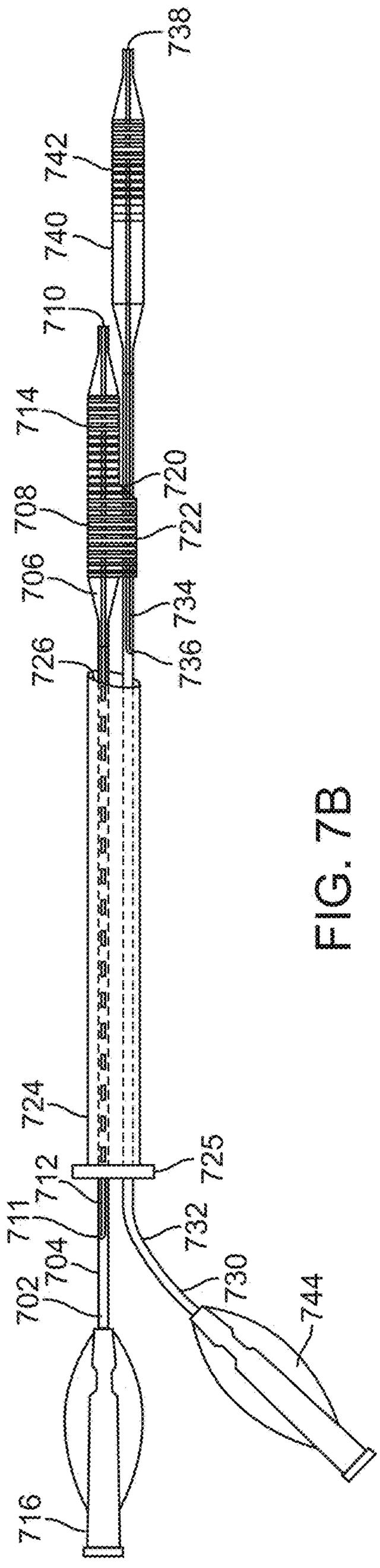
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FIG. 7B

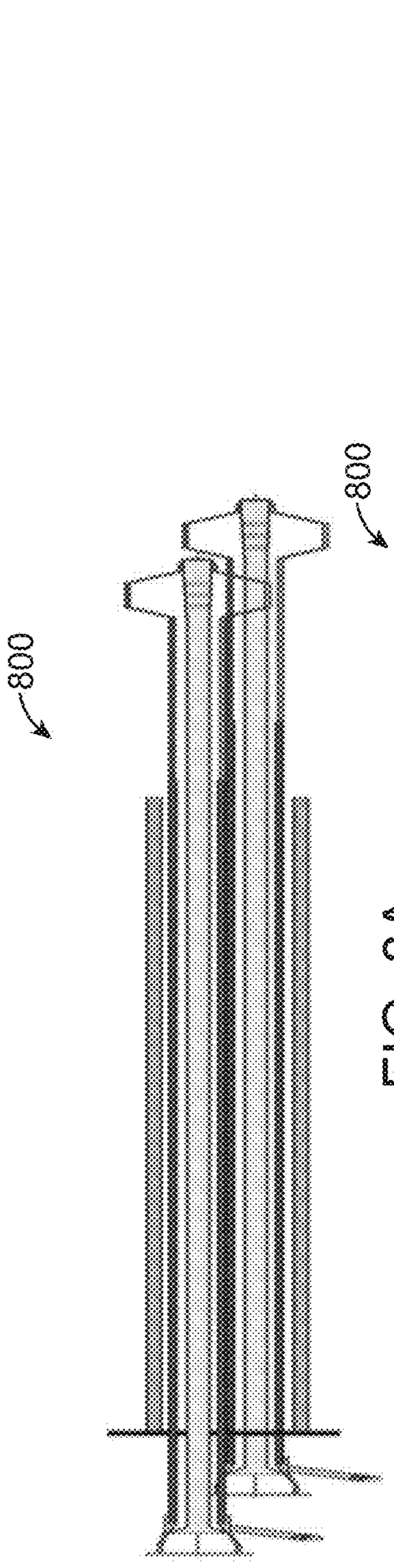
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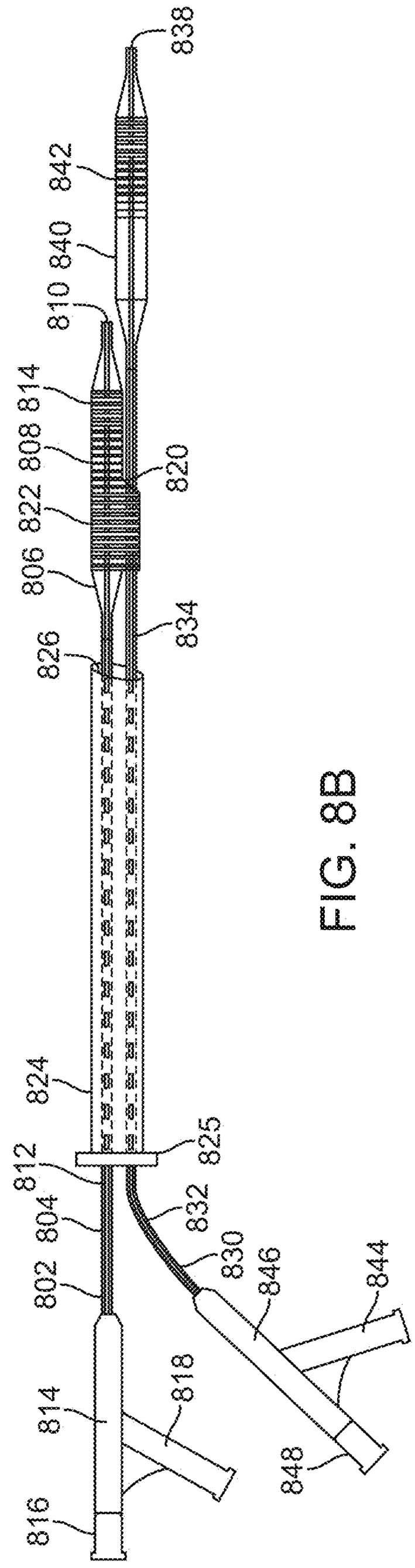
FIG. 8A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816

FIG. 8B

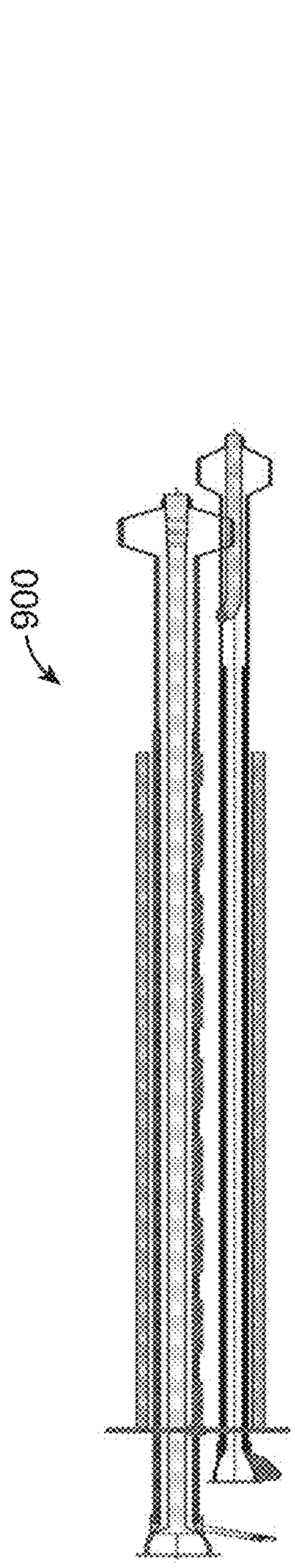
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FIG. 9A

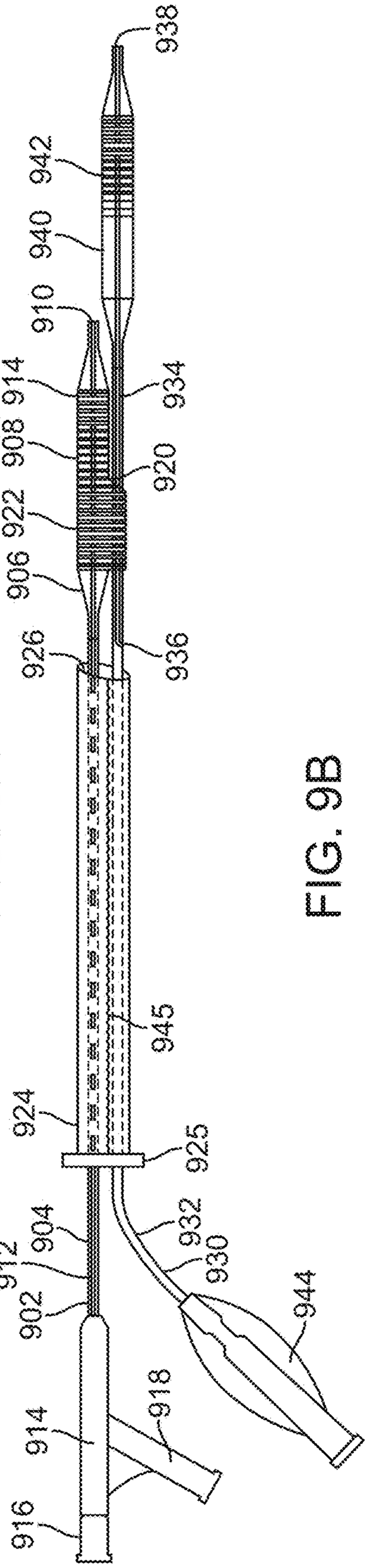
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FIG. 9B

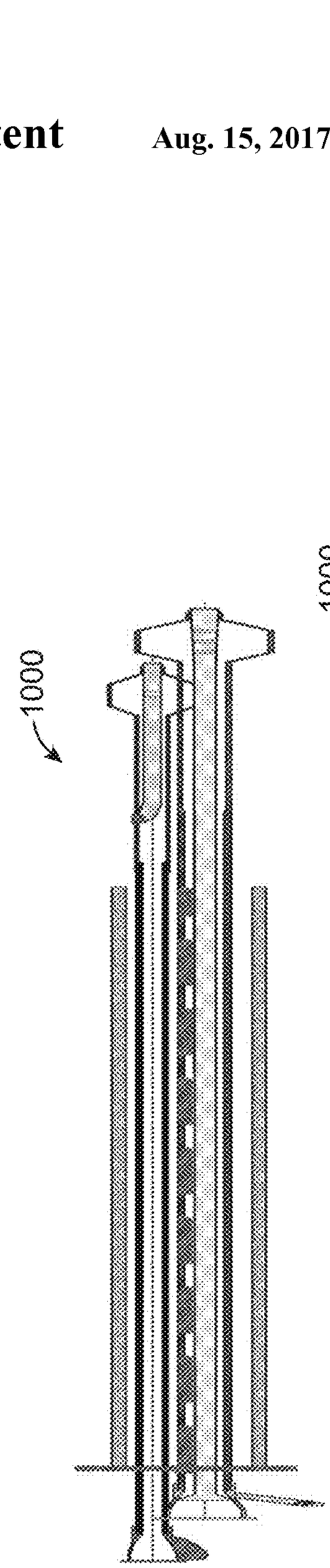

FIG. 10A

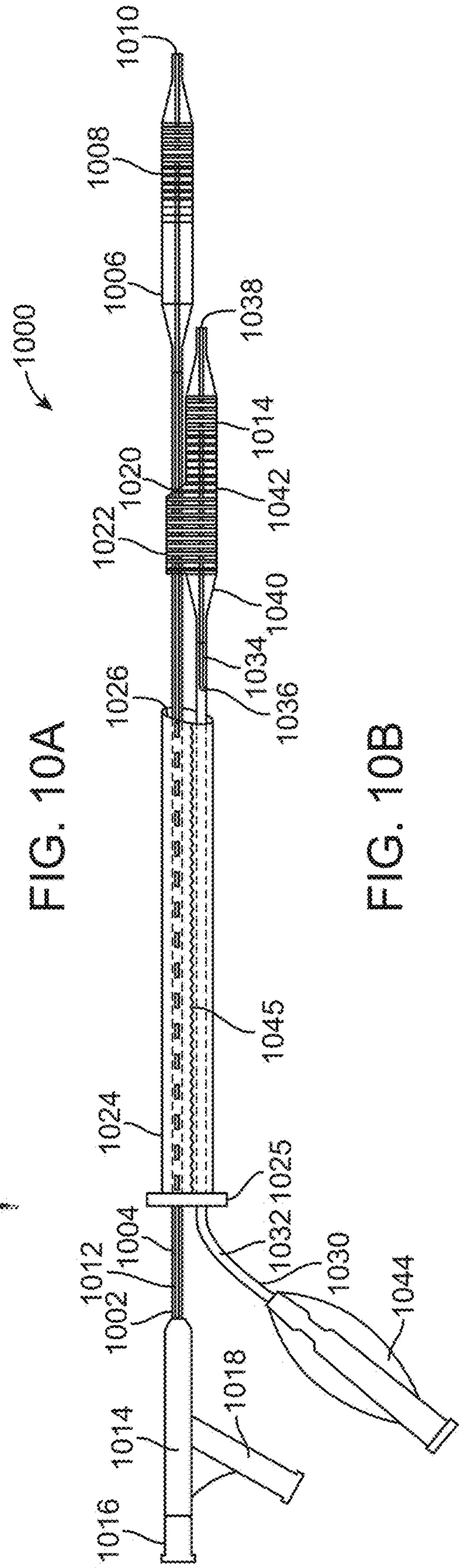

FIG. 10B

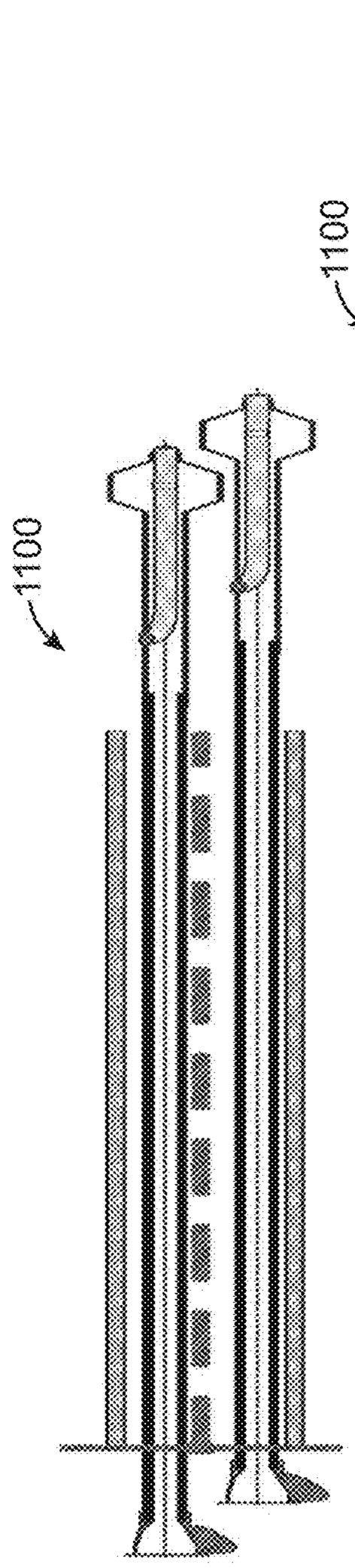

FIG. 11A

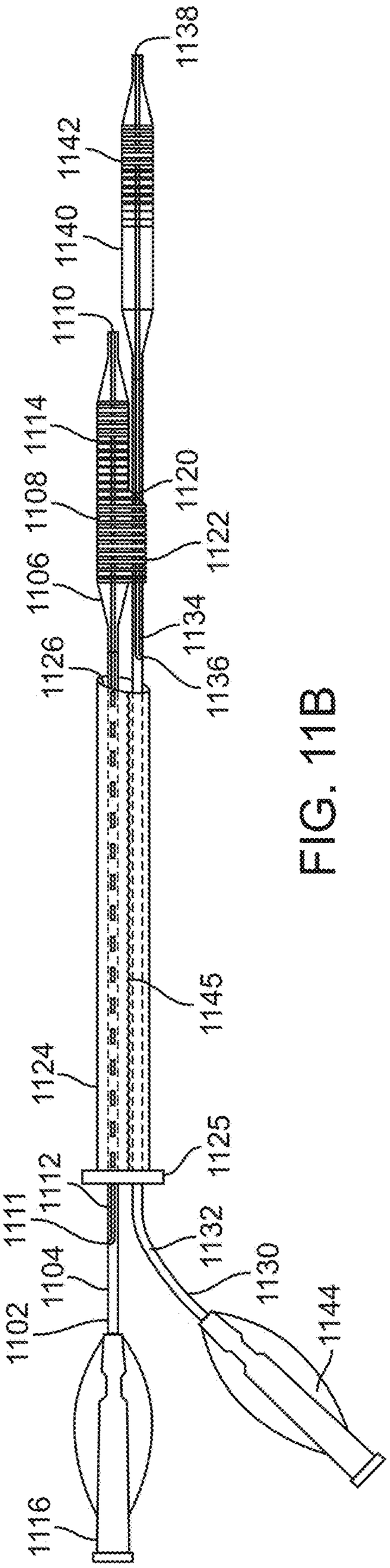

FIG. 11B

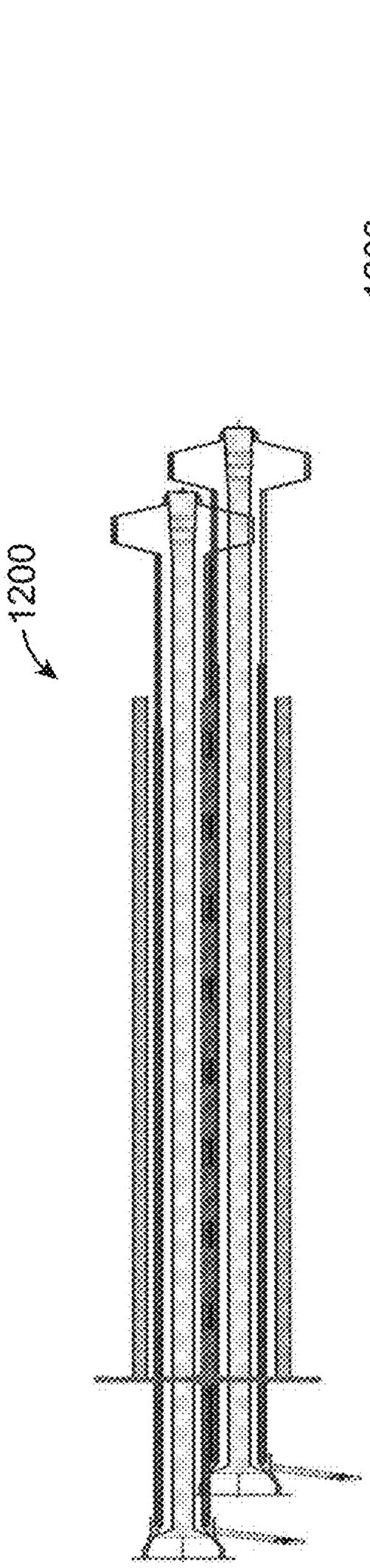

FIG. 12A

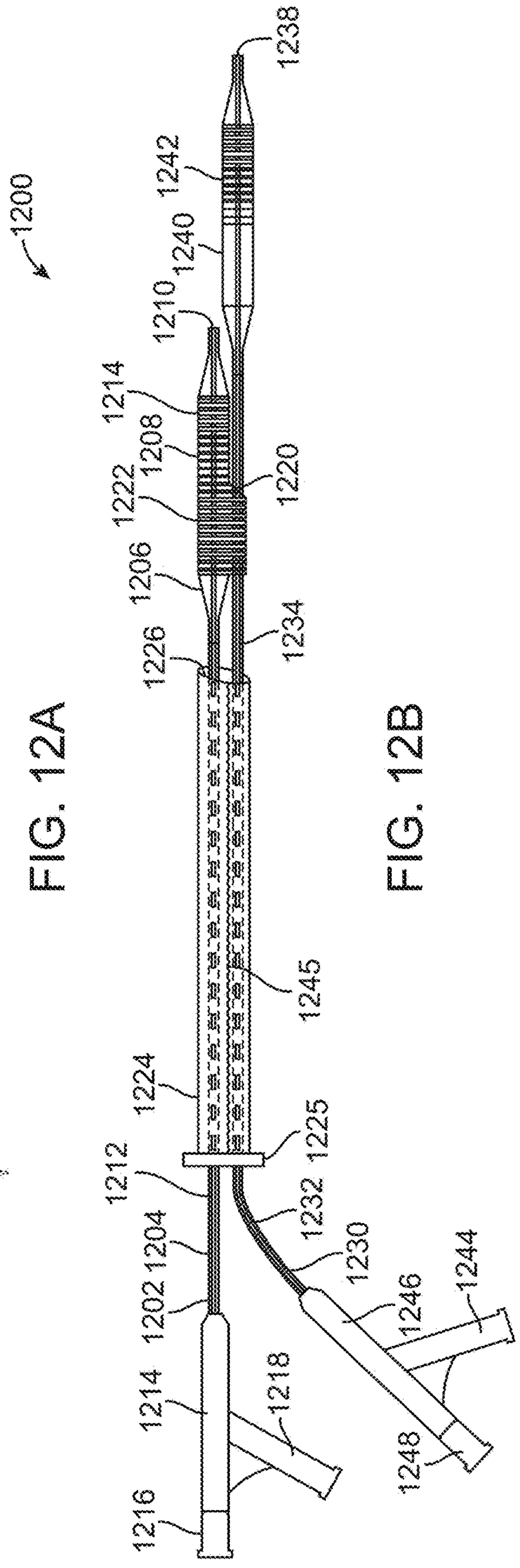

FIG. 12B

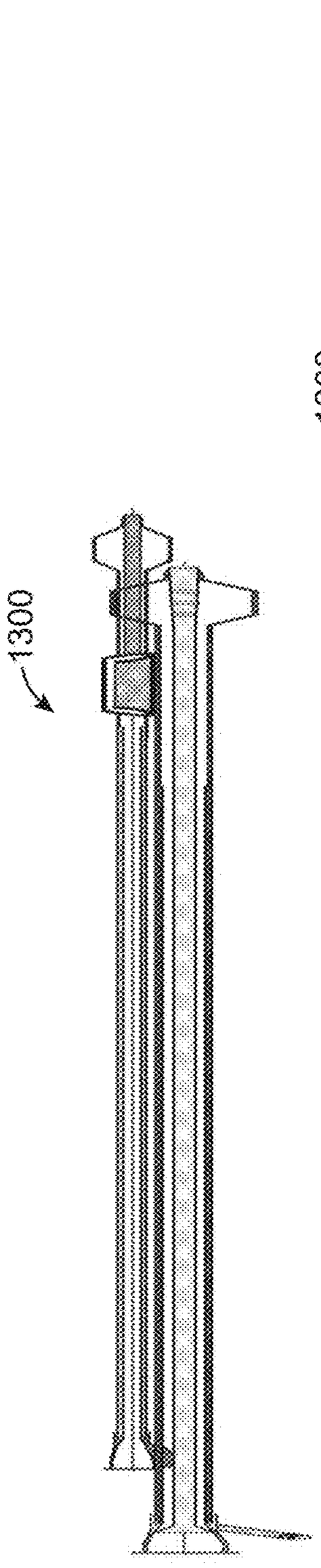

FIG. 13A

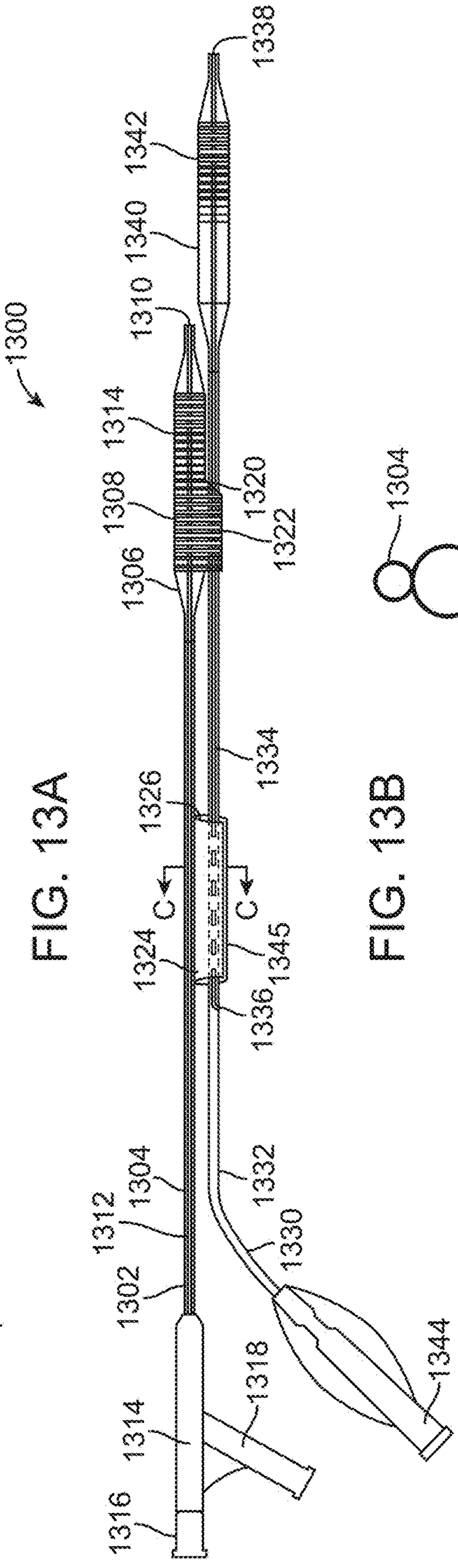

FIG. 13B

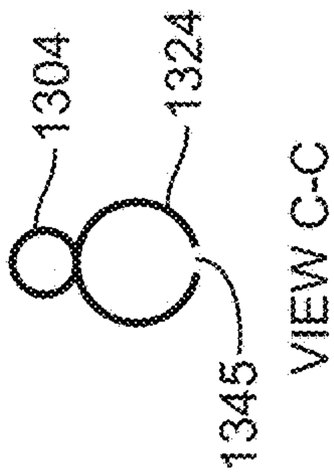

FIG. 13C

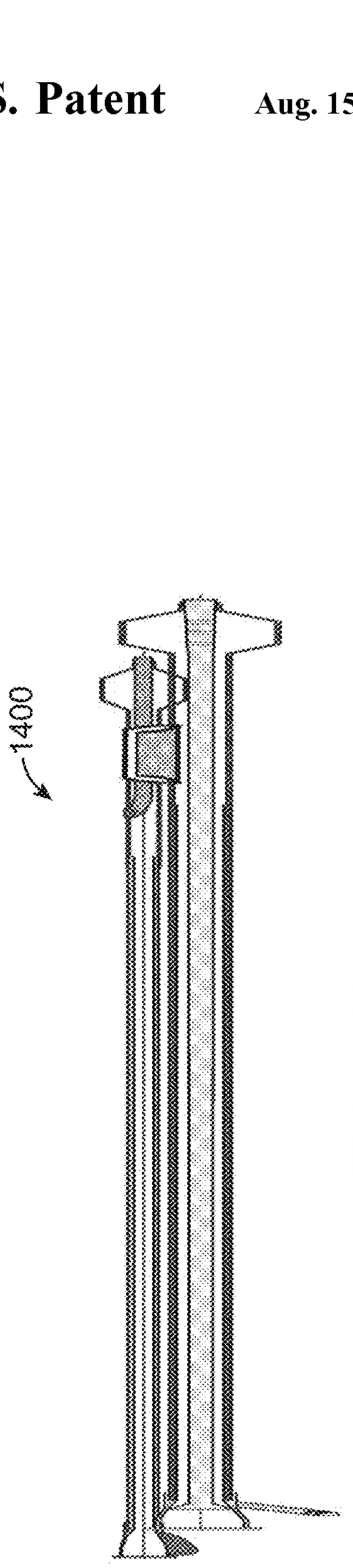

FIG. 14A

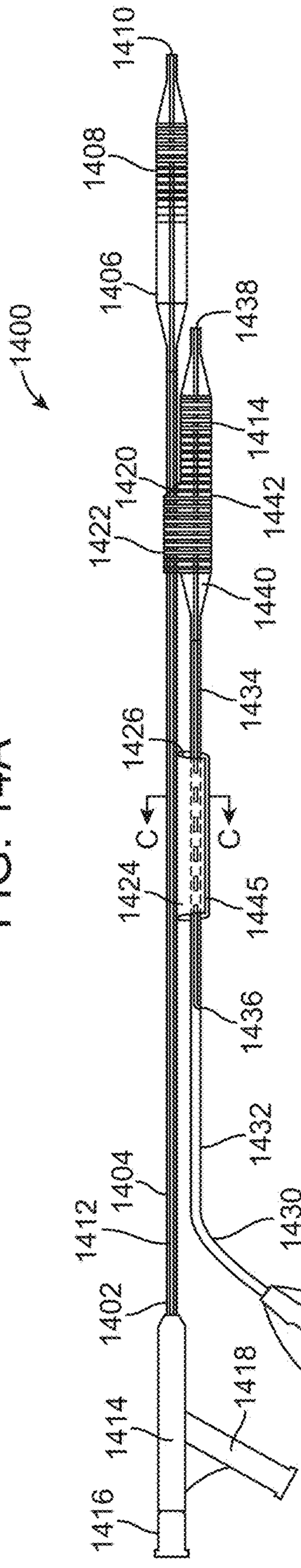

FIG. 14B

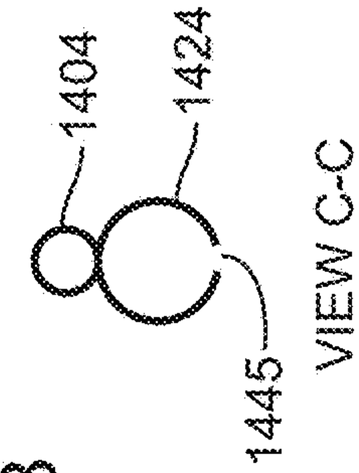

FIG. 14C

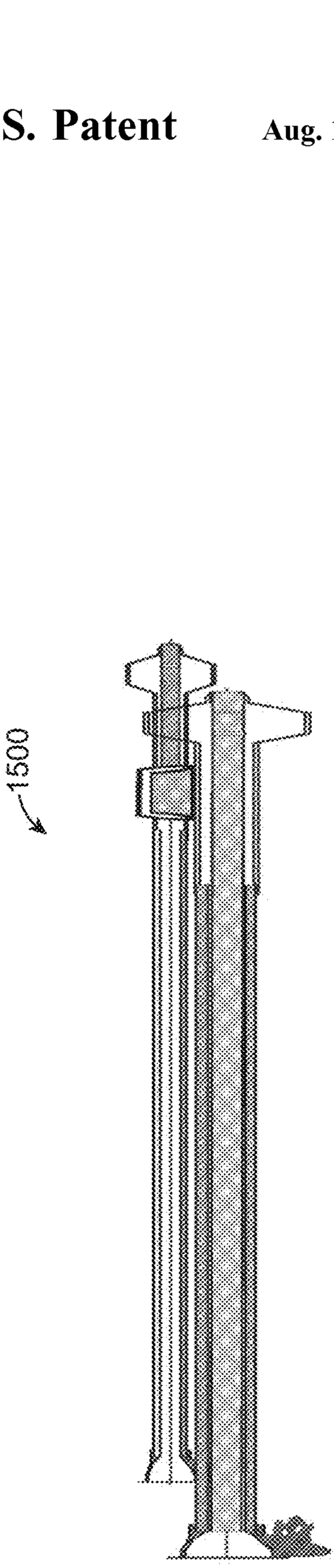

FIG. 15A

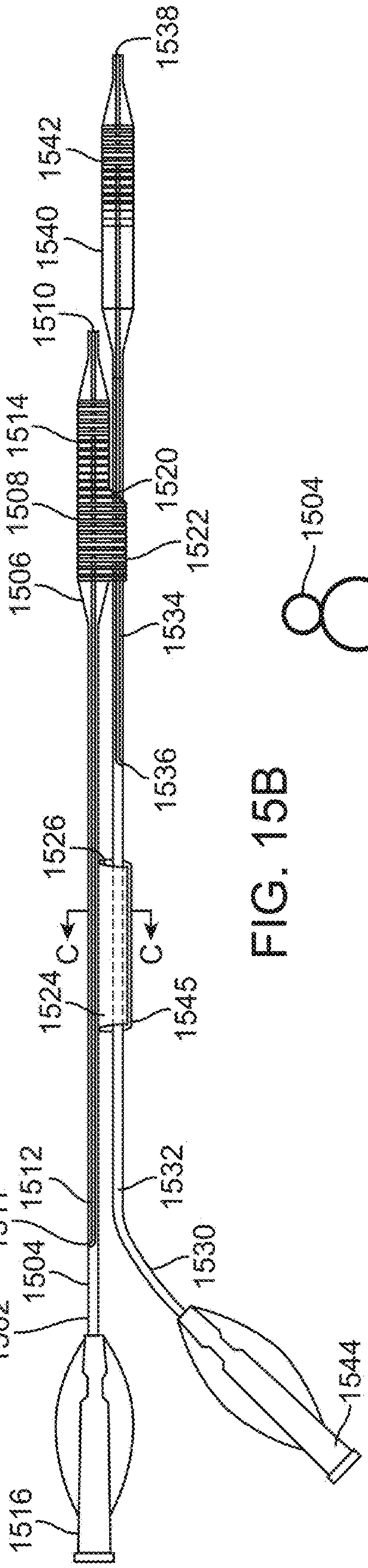

FIG. 15B

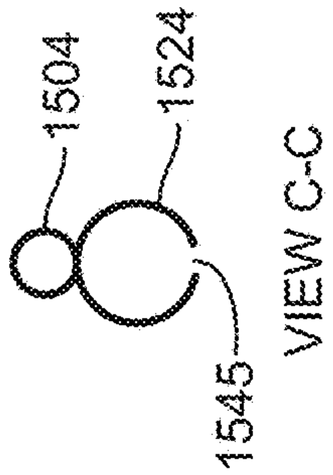

FIG. 15C

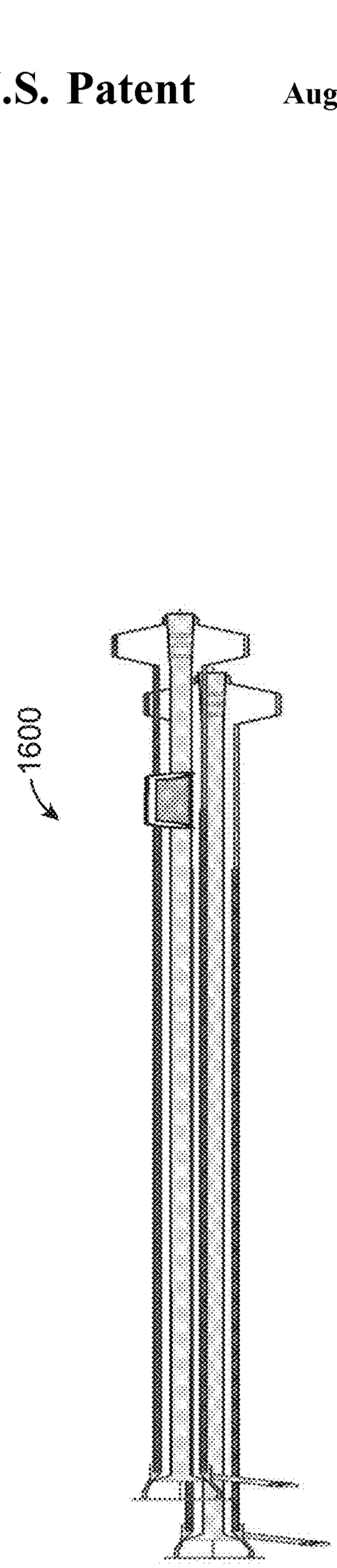

FIG. 16A

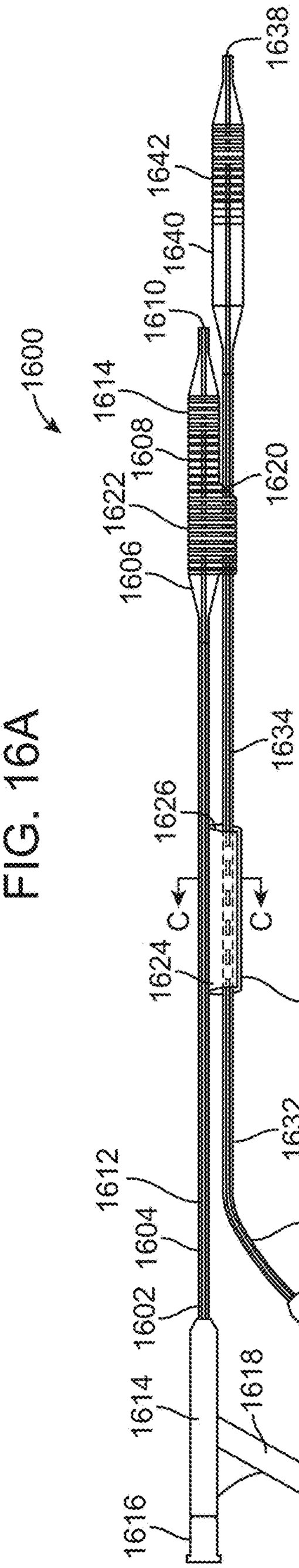

FIG. 16B

FIG. 16C

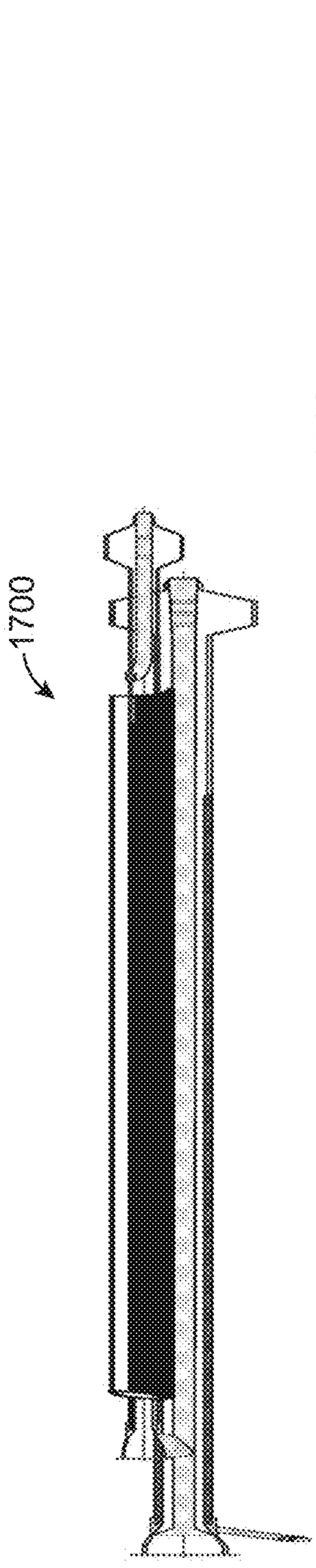

FIG. 17A

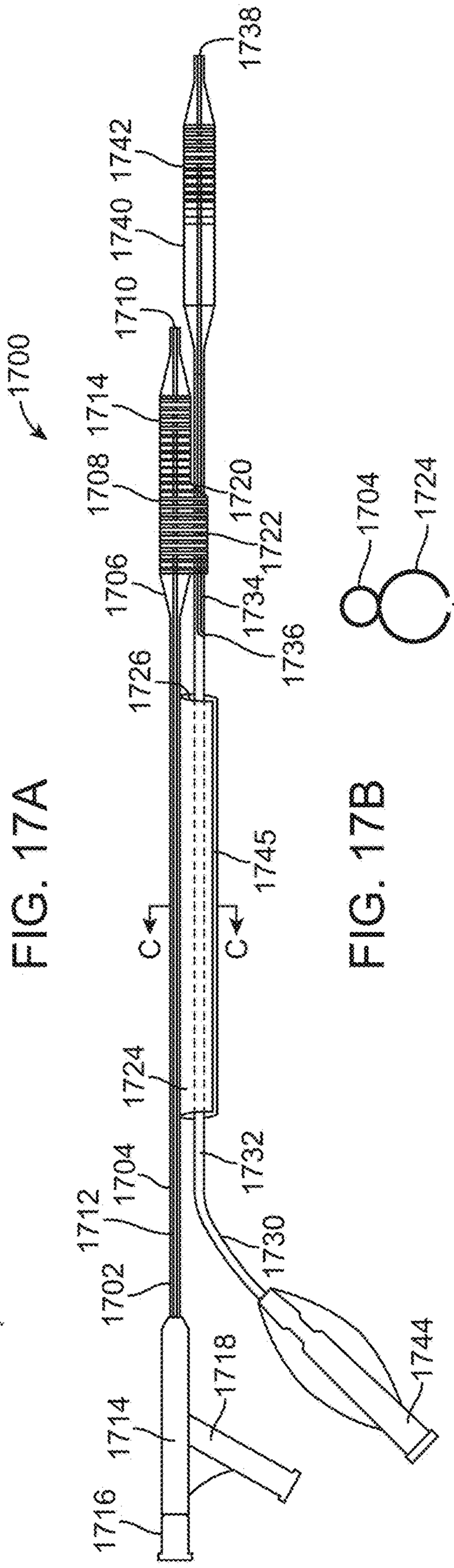

FIG. 17B

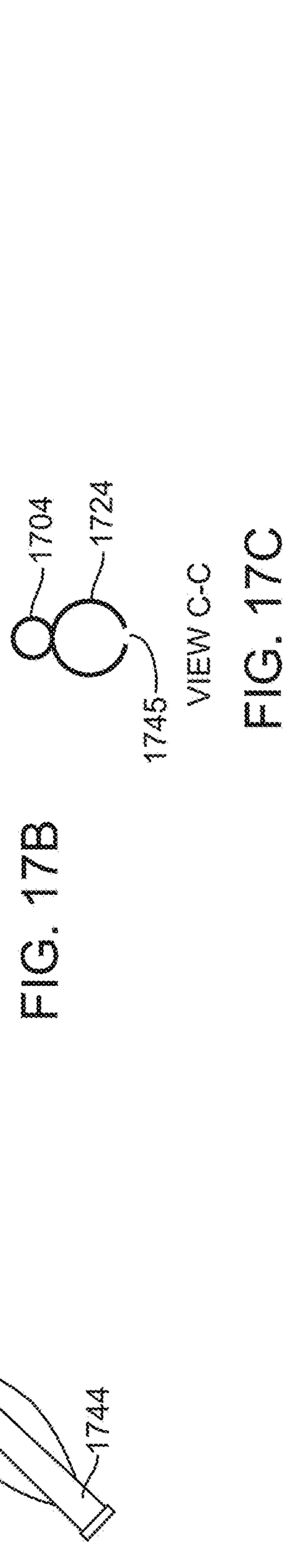

FIG. 17C

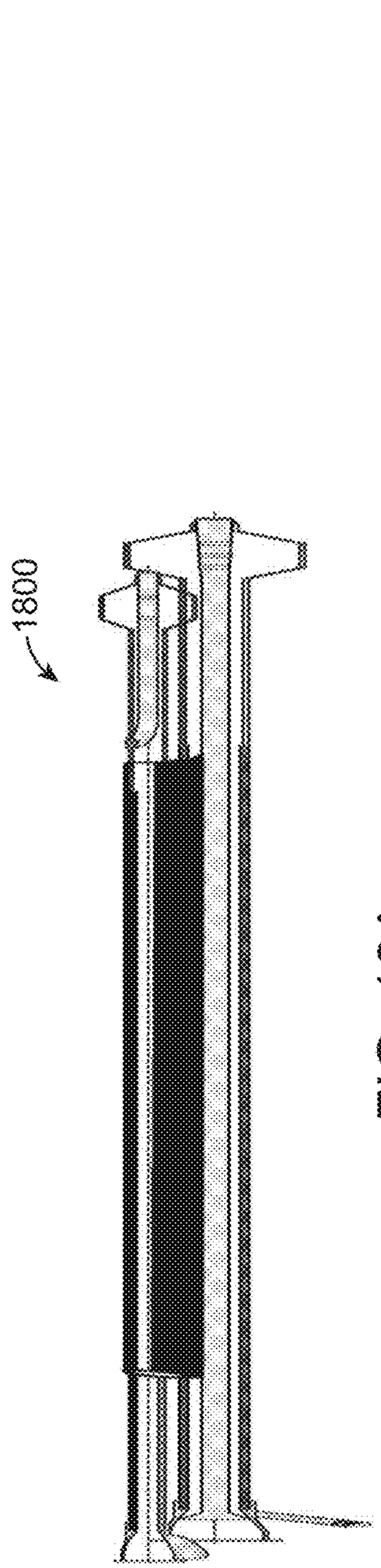

FIG. 18A

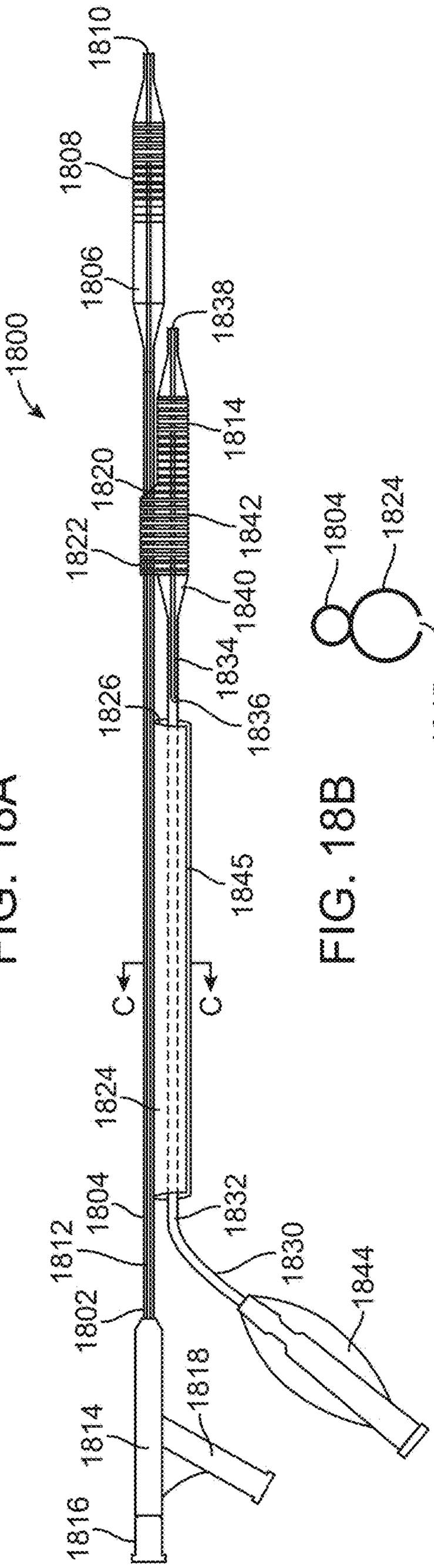

FIG. 18B

FIG. 18C

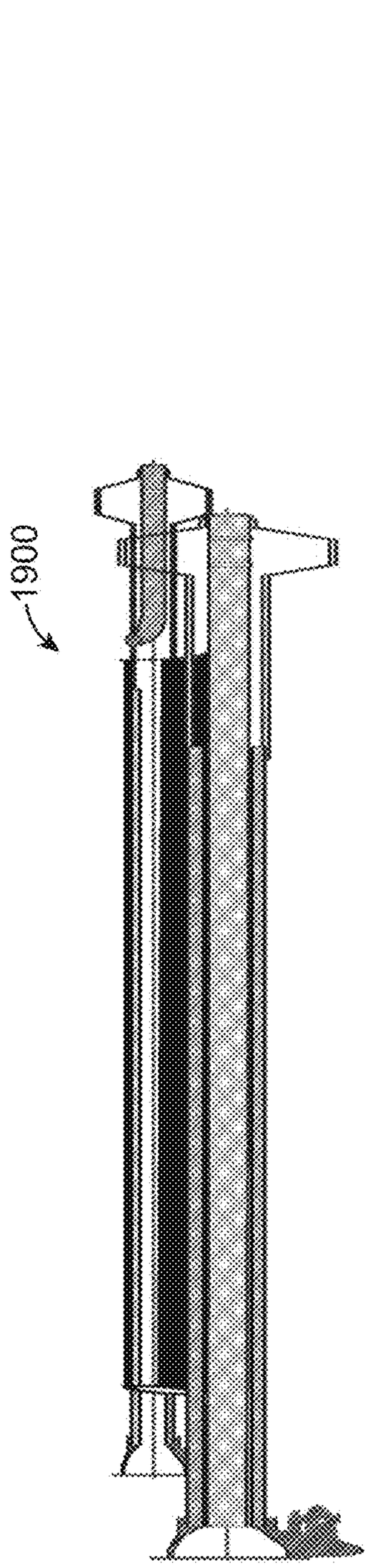

FIG. 19A

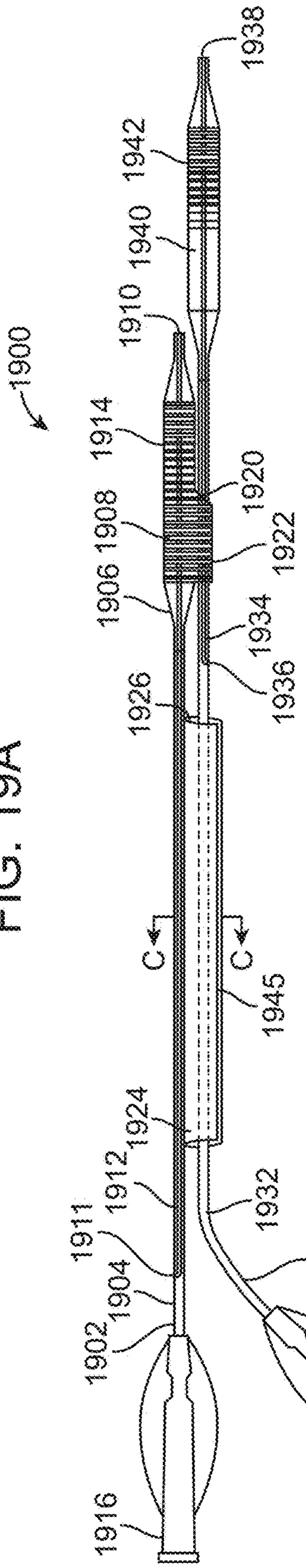

FIG. 19B

FIG. 19C

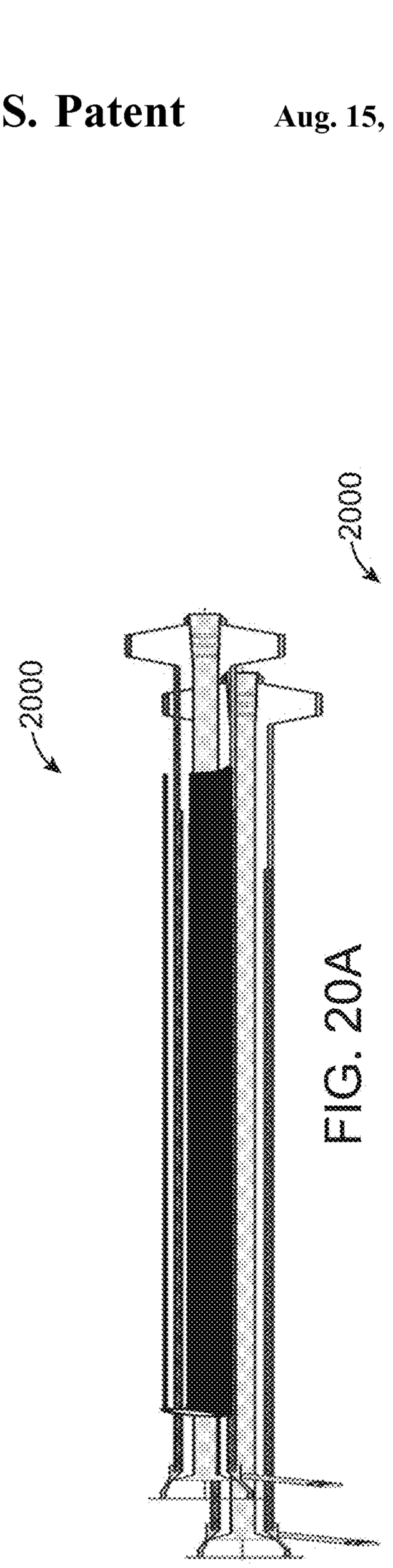

FIG. 20A

FIG. 20B

FIG. 20C

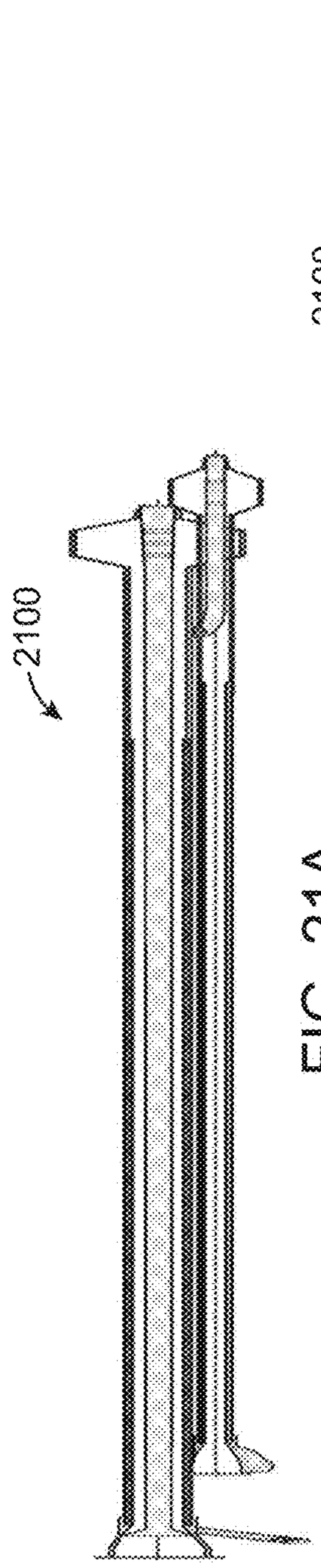

FIG. 21A

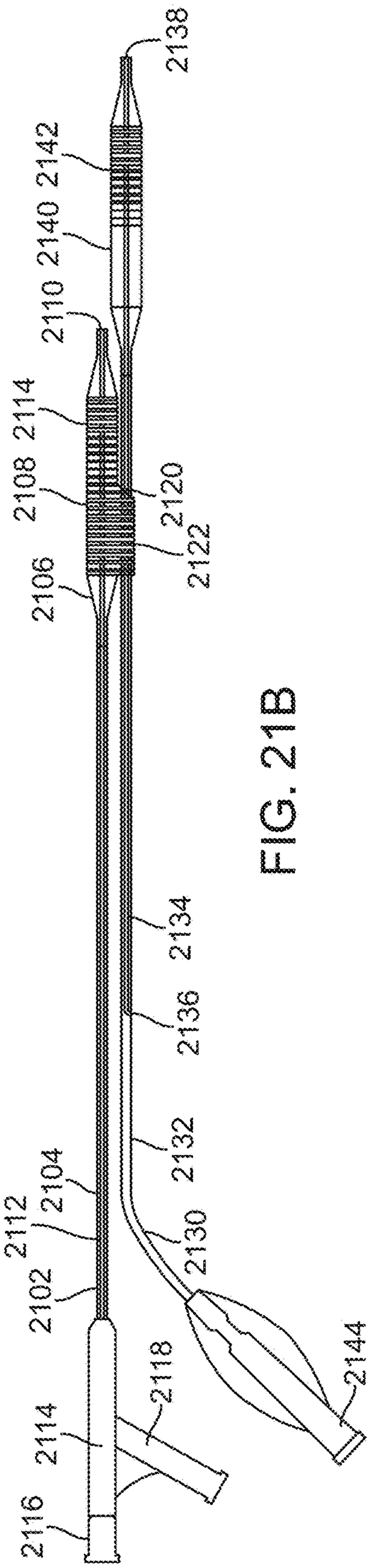

FIG. 21B

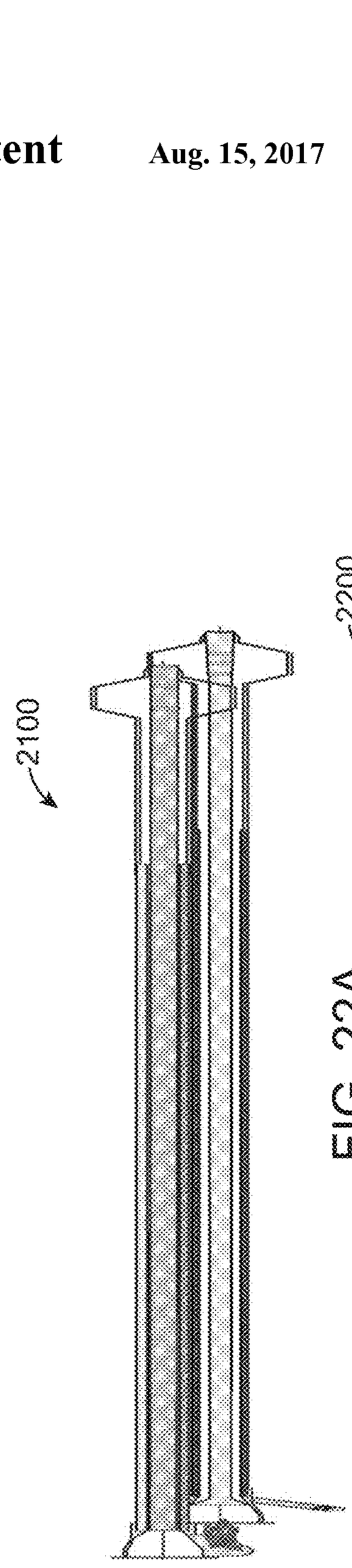

FIG. 22A

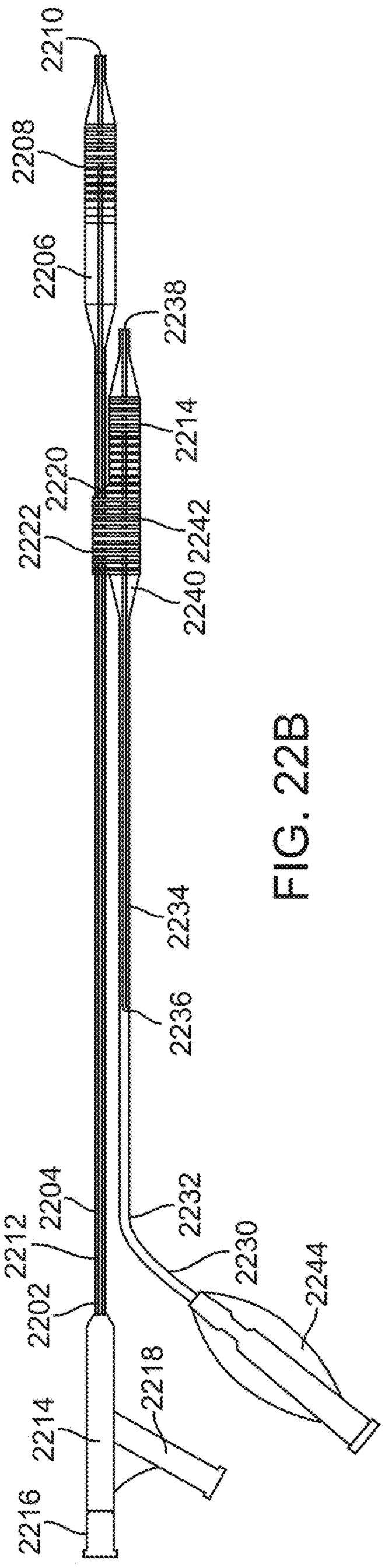

FIG. 22B

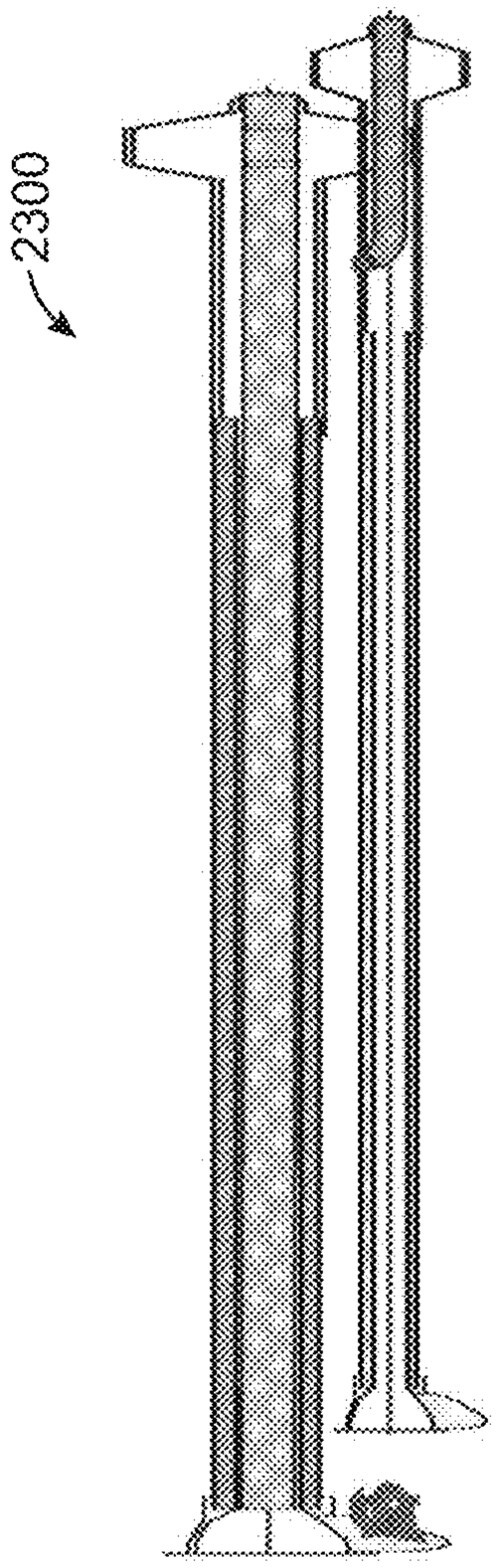

FIG. 23A

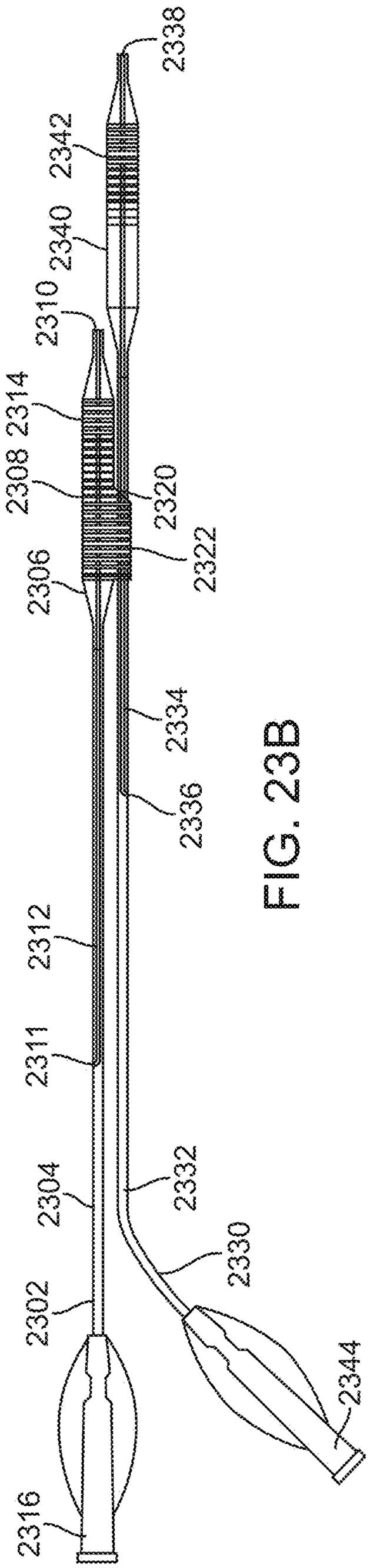

FIG. 23B

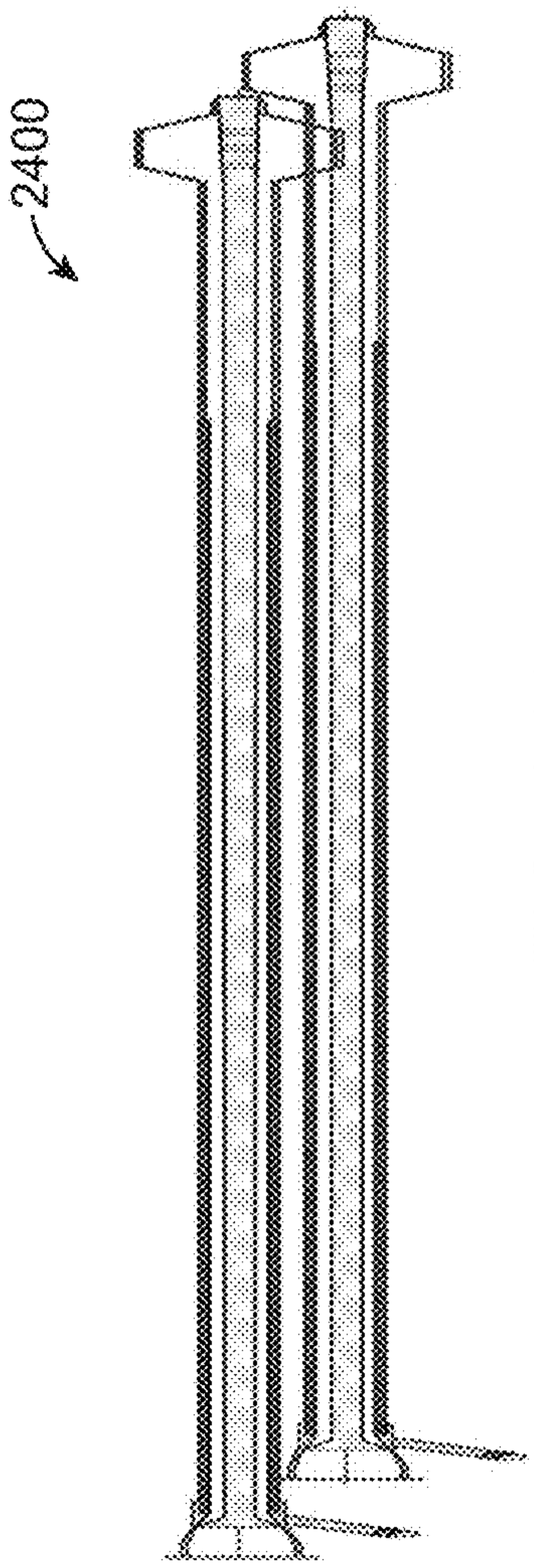

FIG. 24A

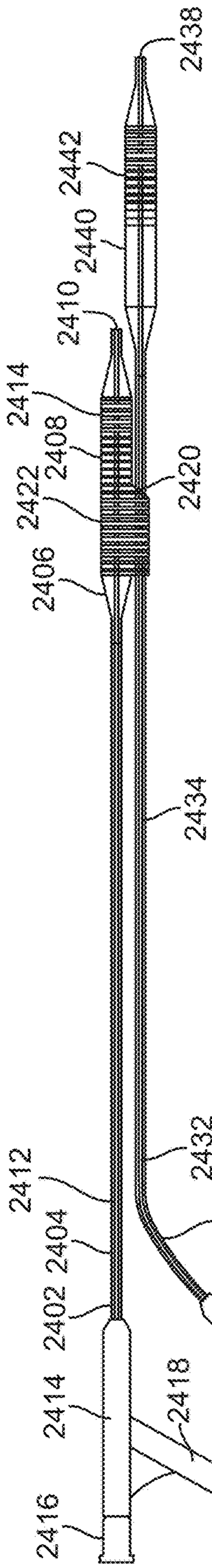

FIG. 24B

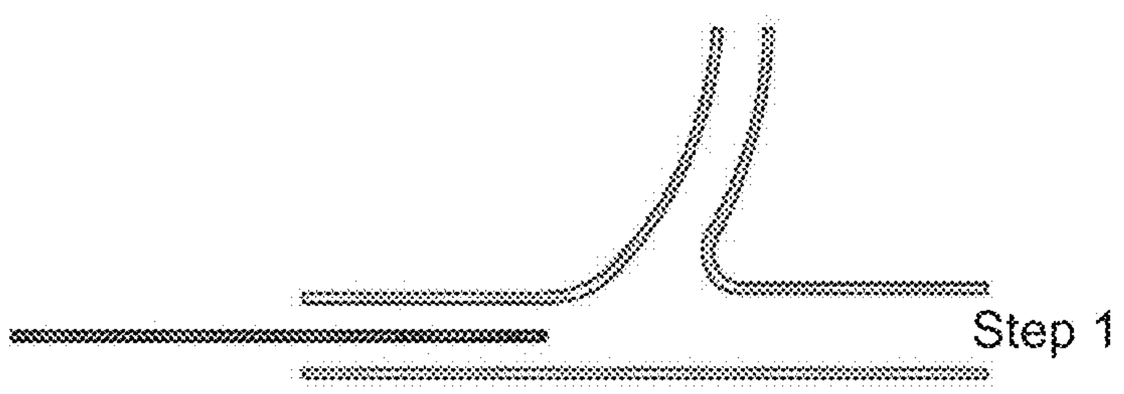

FIG. 25A

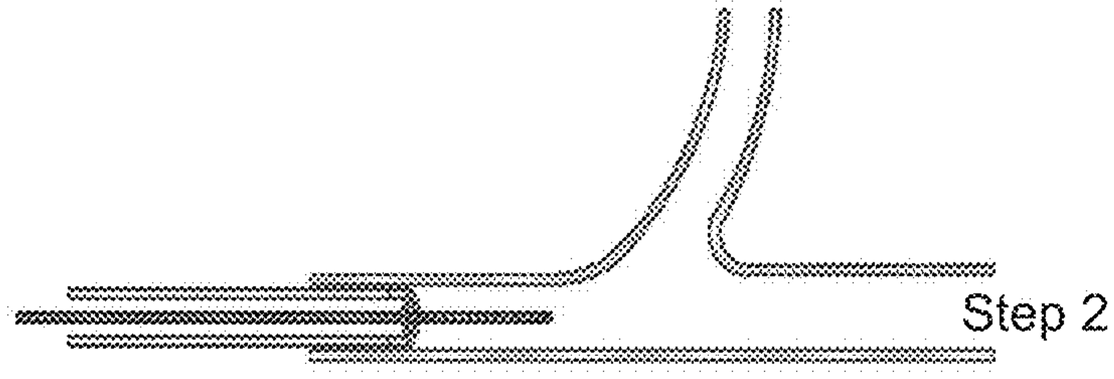

FIG. 25B

FIG. 26A

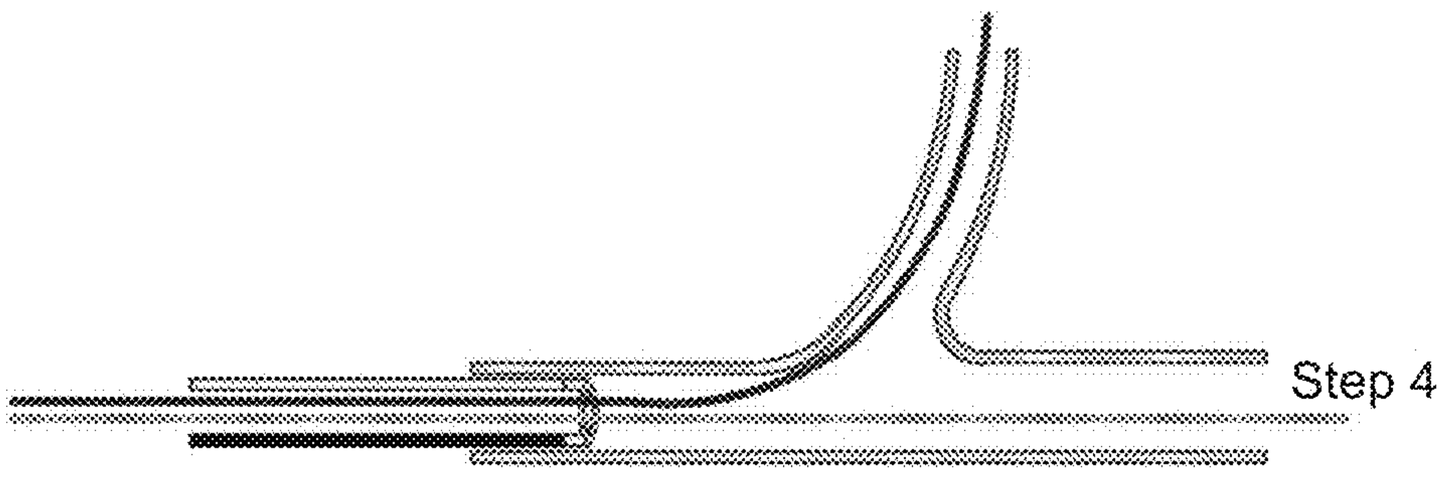

FIG. 26B

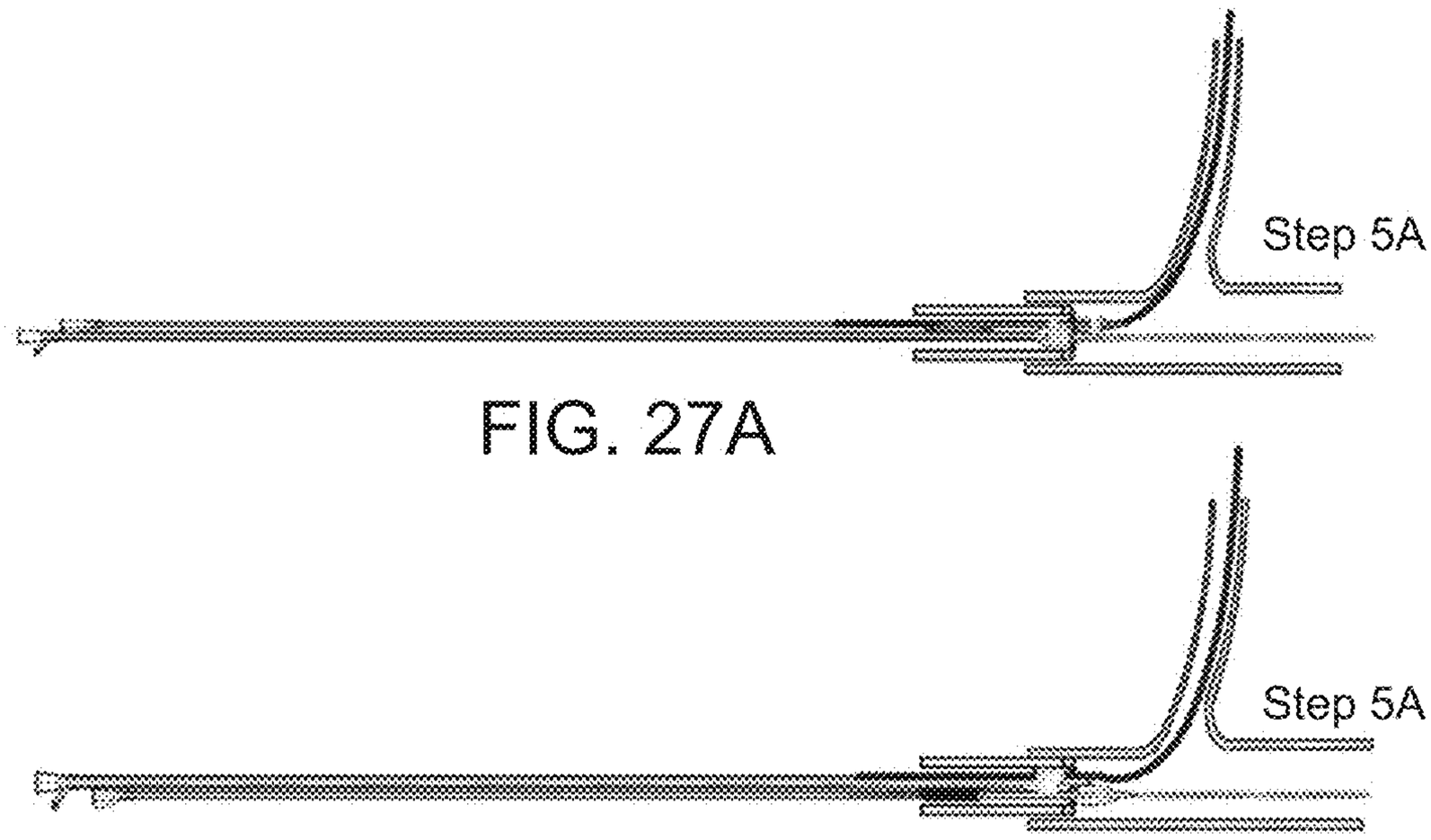

FIG. 27A

FIG. 27B

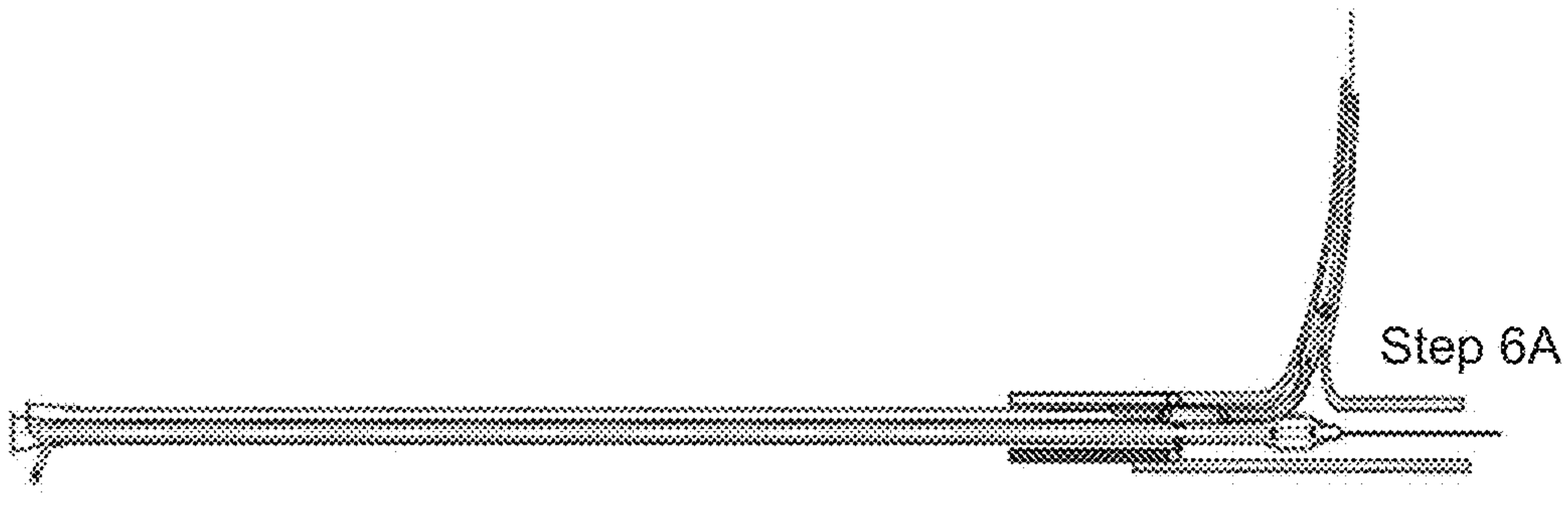

FIG. 28A

FIG. 28B

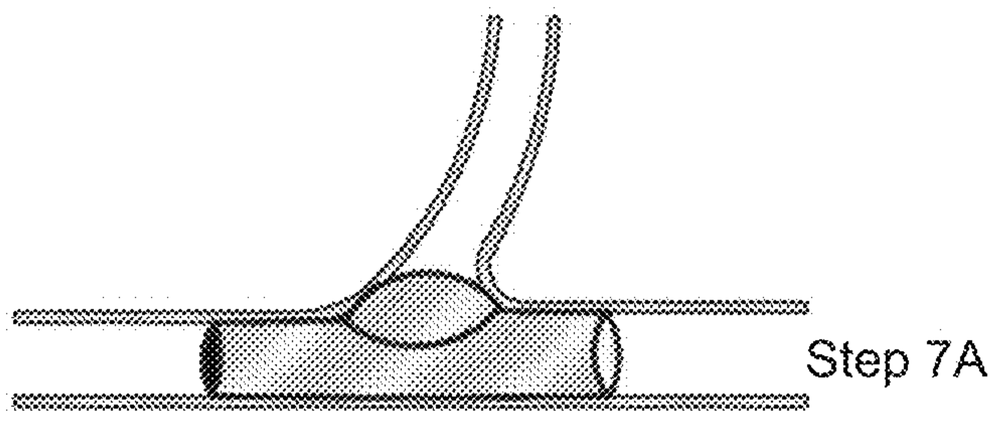

FIG. 29A

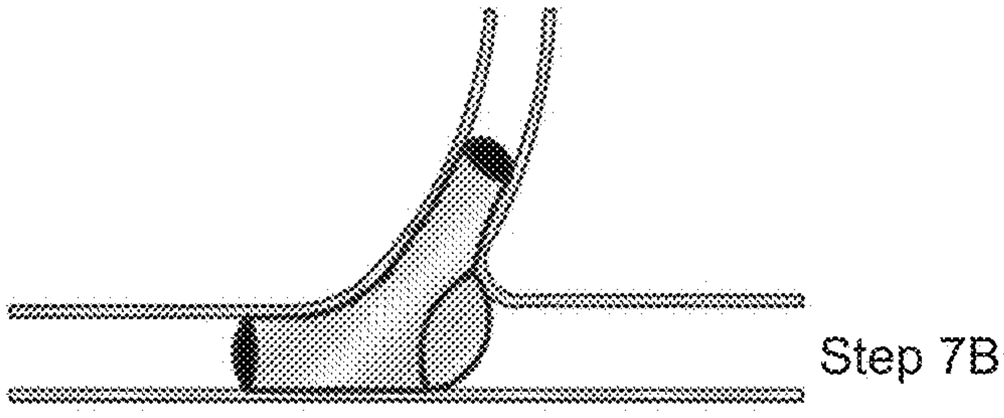

FIG. 29B

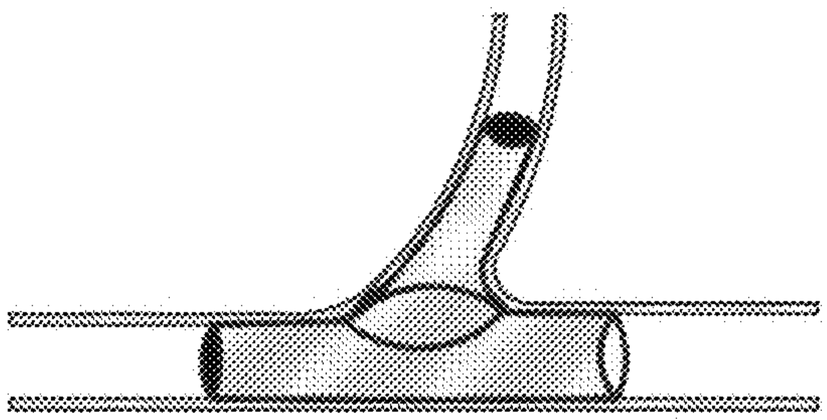

FIG. 30A

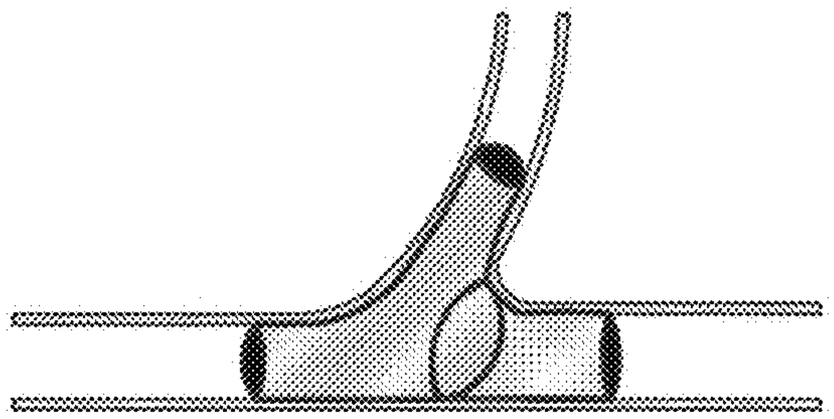

FIG. 30B

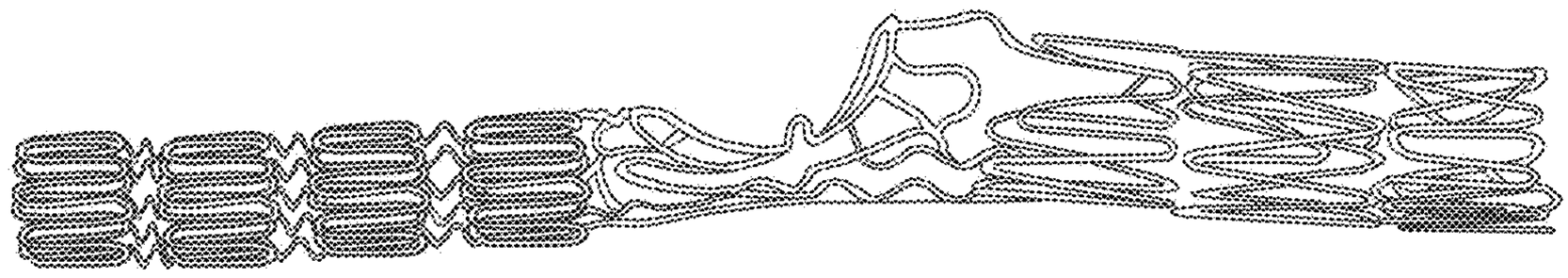

FIG. 31

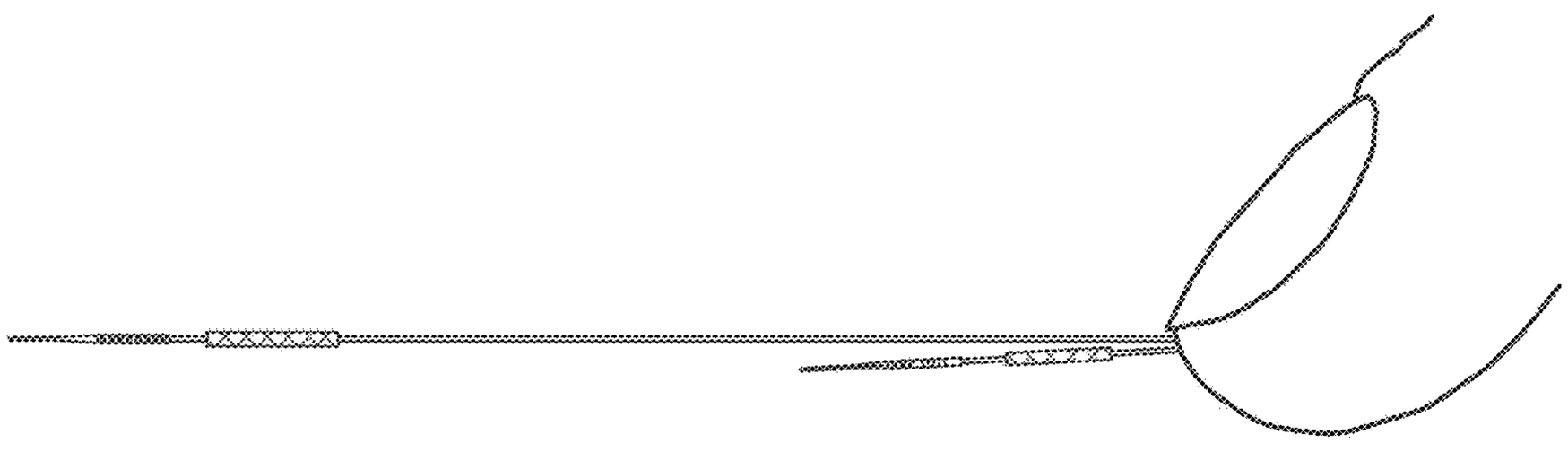

FIG. 32

FIG. 33

FIG. 34

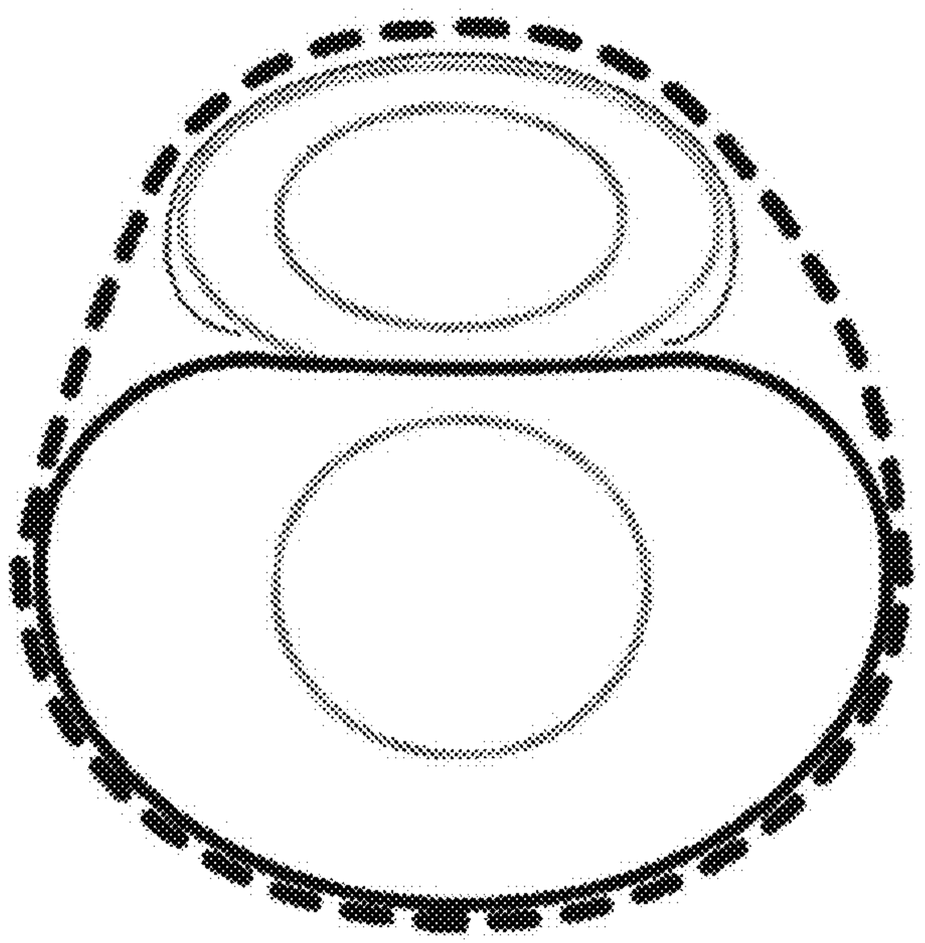

FIG. 35

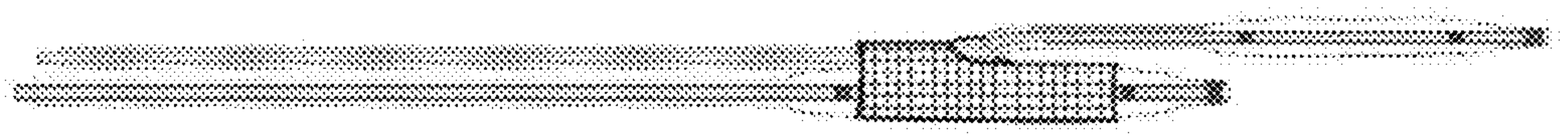

FIG. 36

FIG. 37

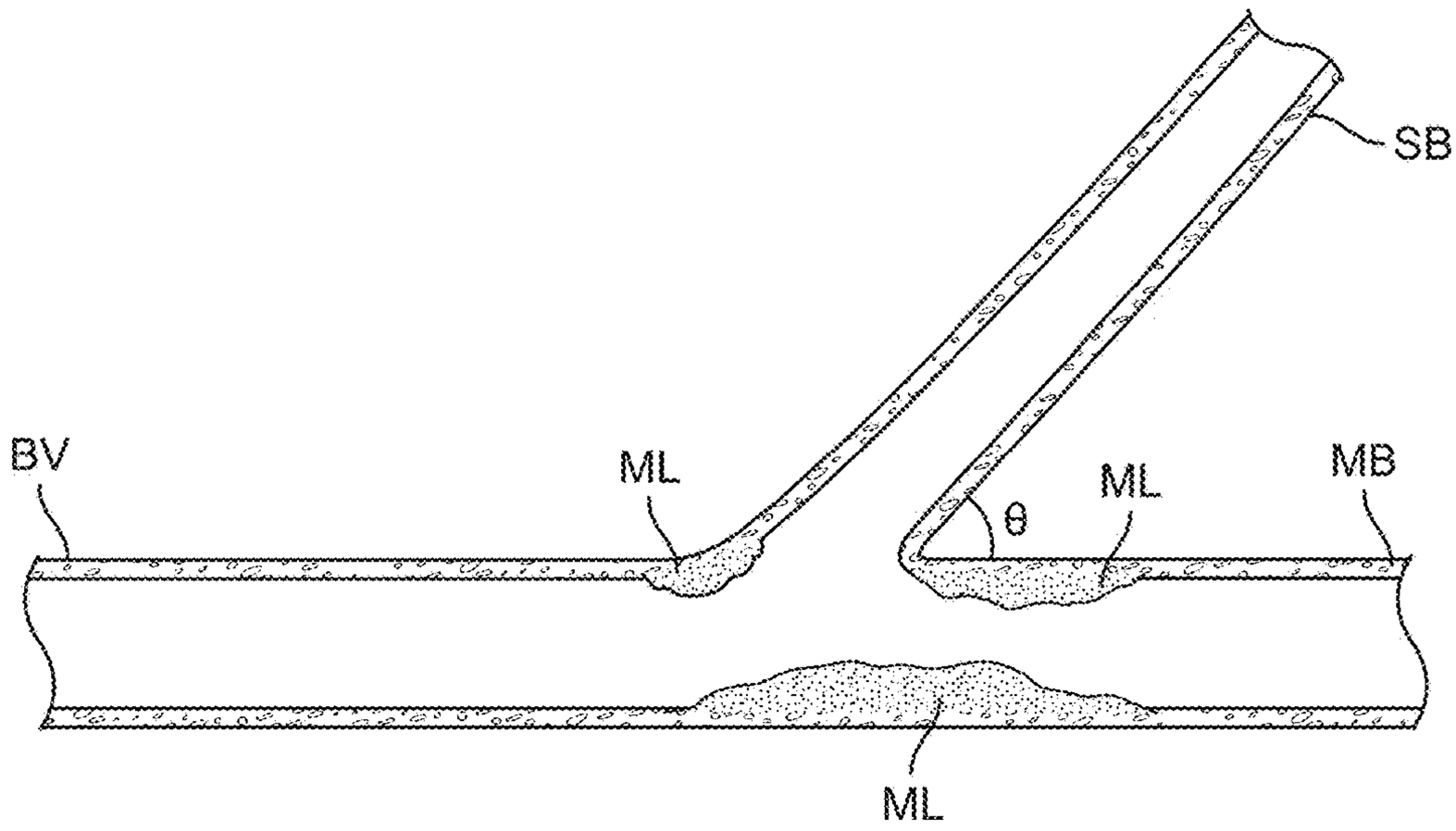

FIG. 38A

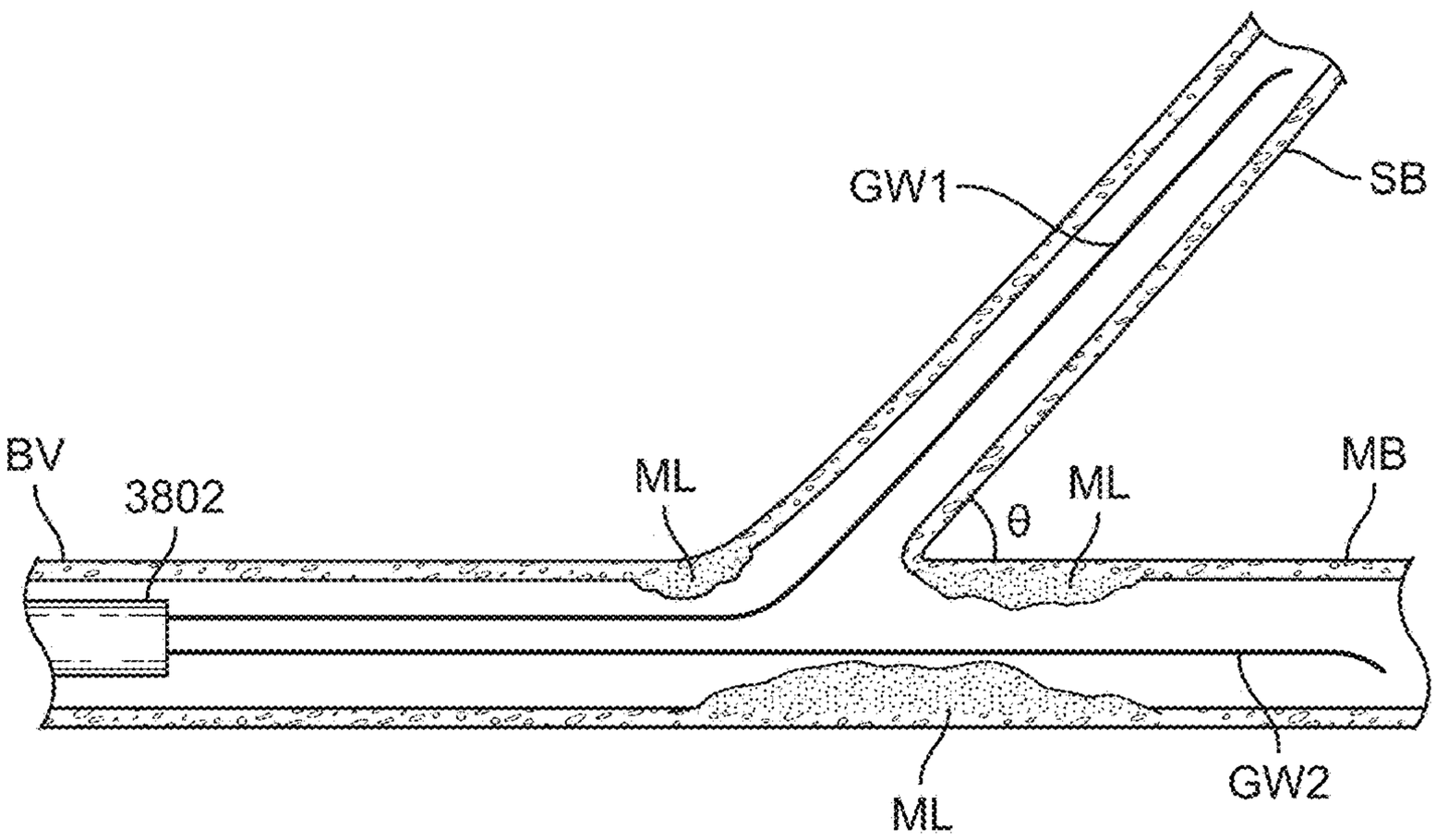

FIG. 38B

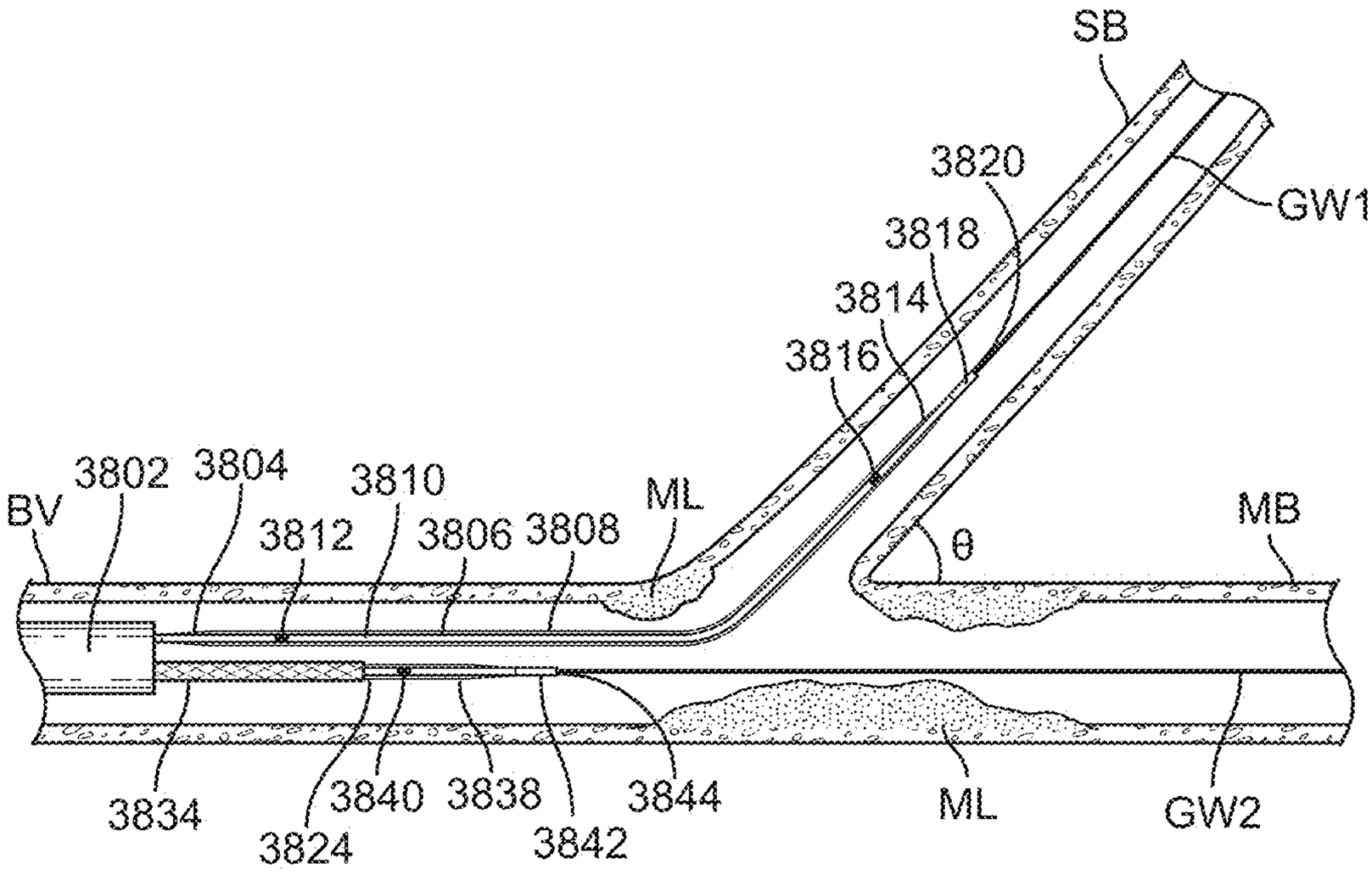

FIG. 38C

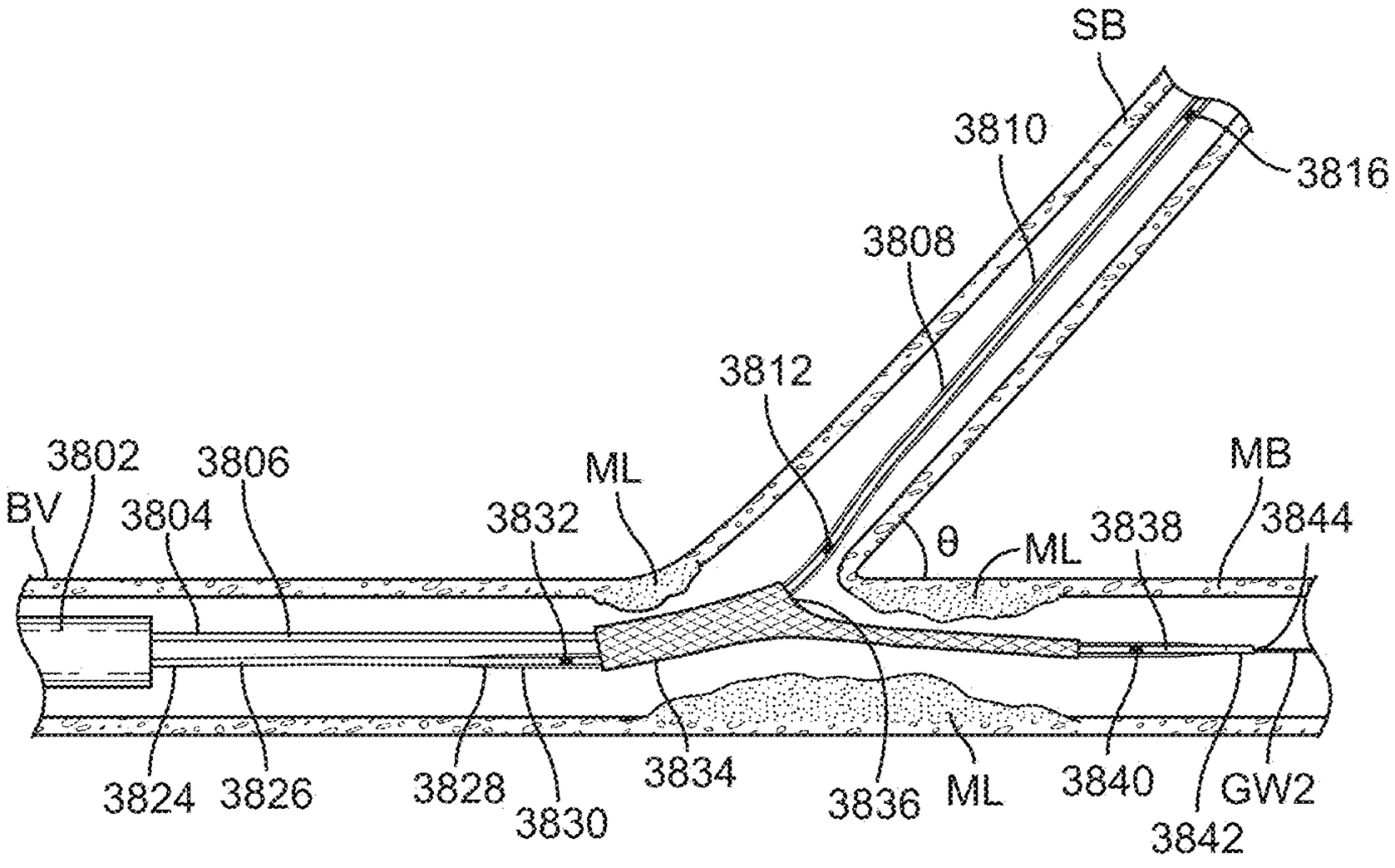

FIG. 38D

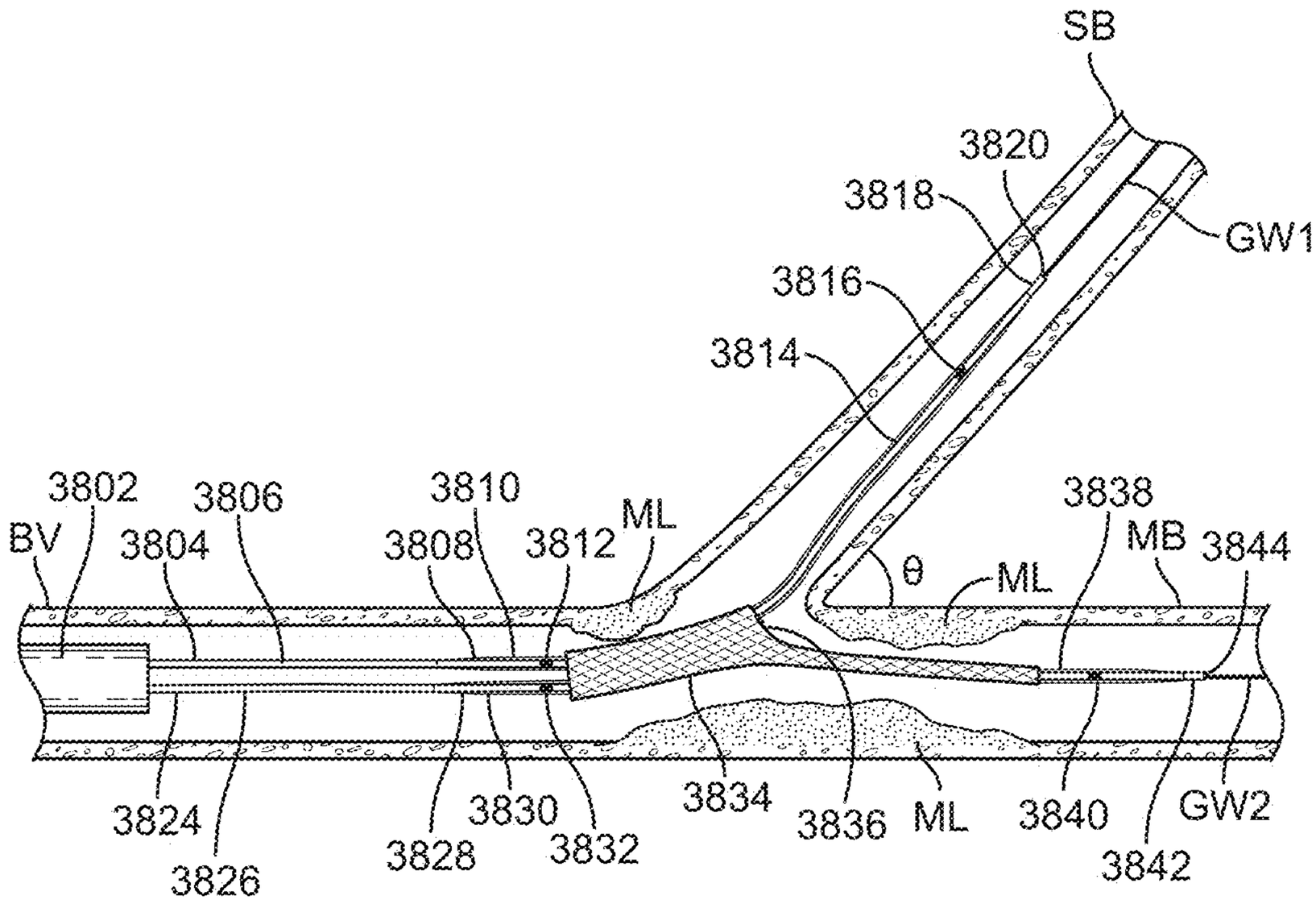

FIG. 38E

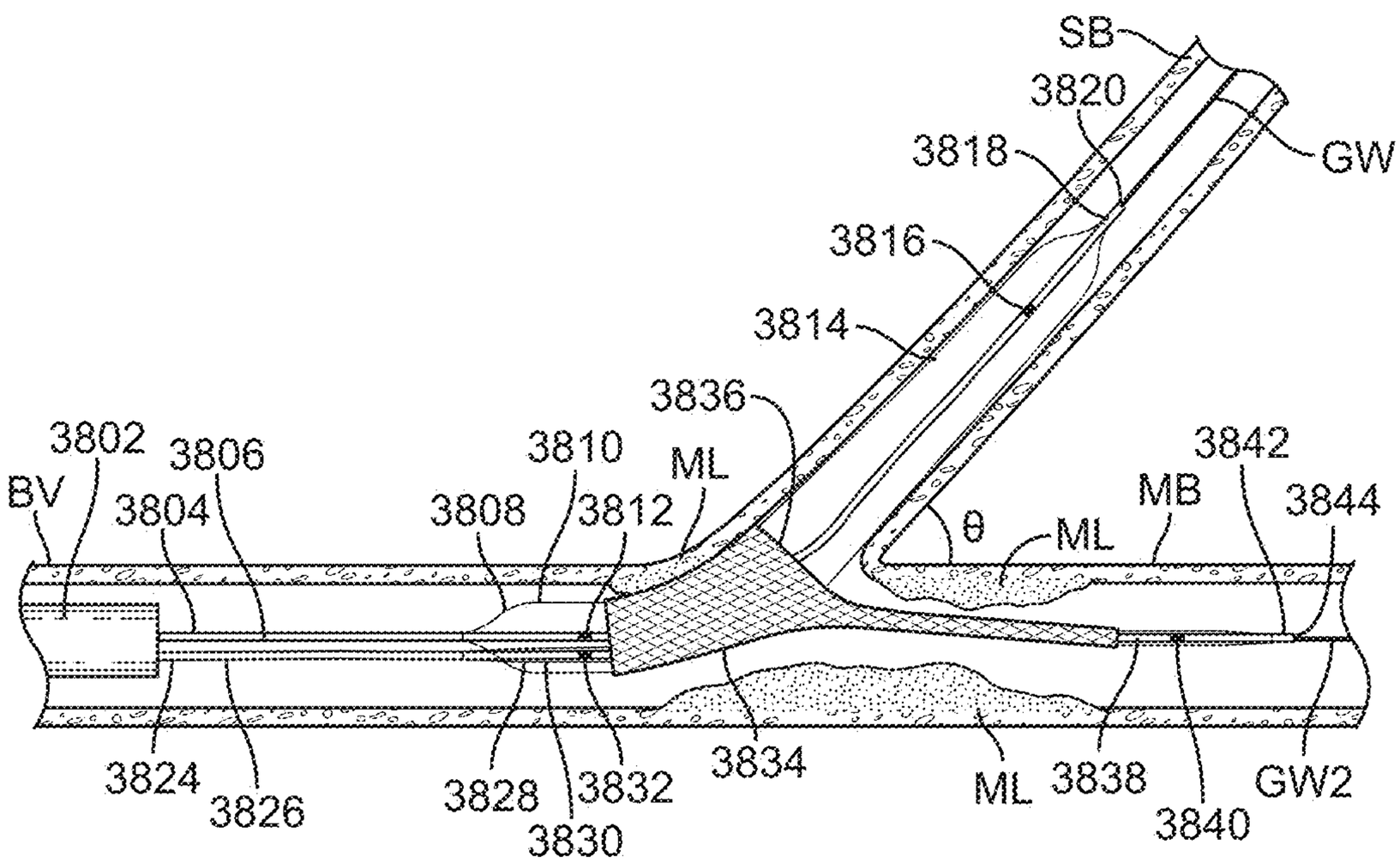

FIG. 38F

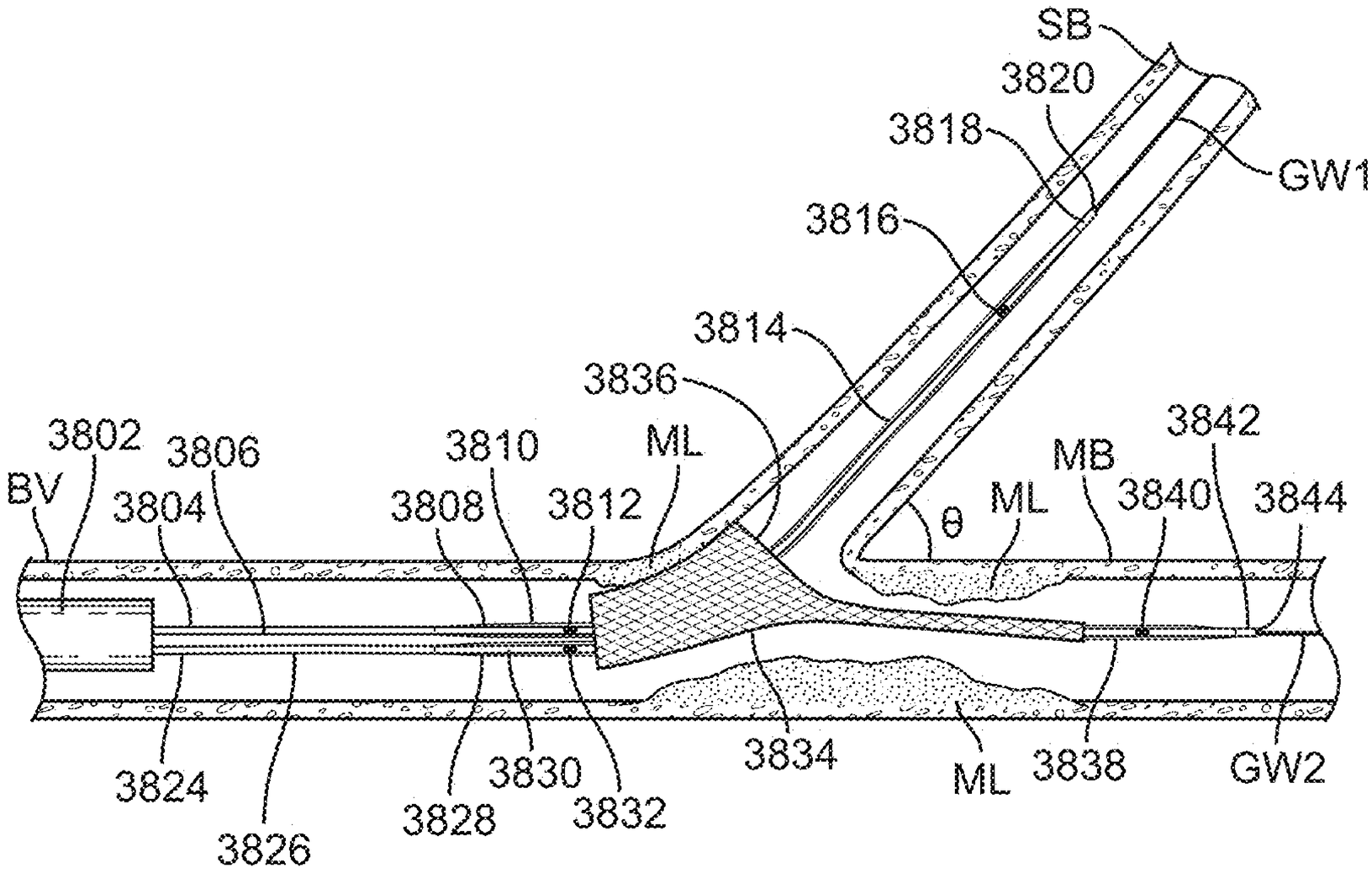

FIG. 38G

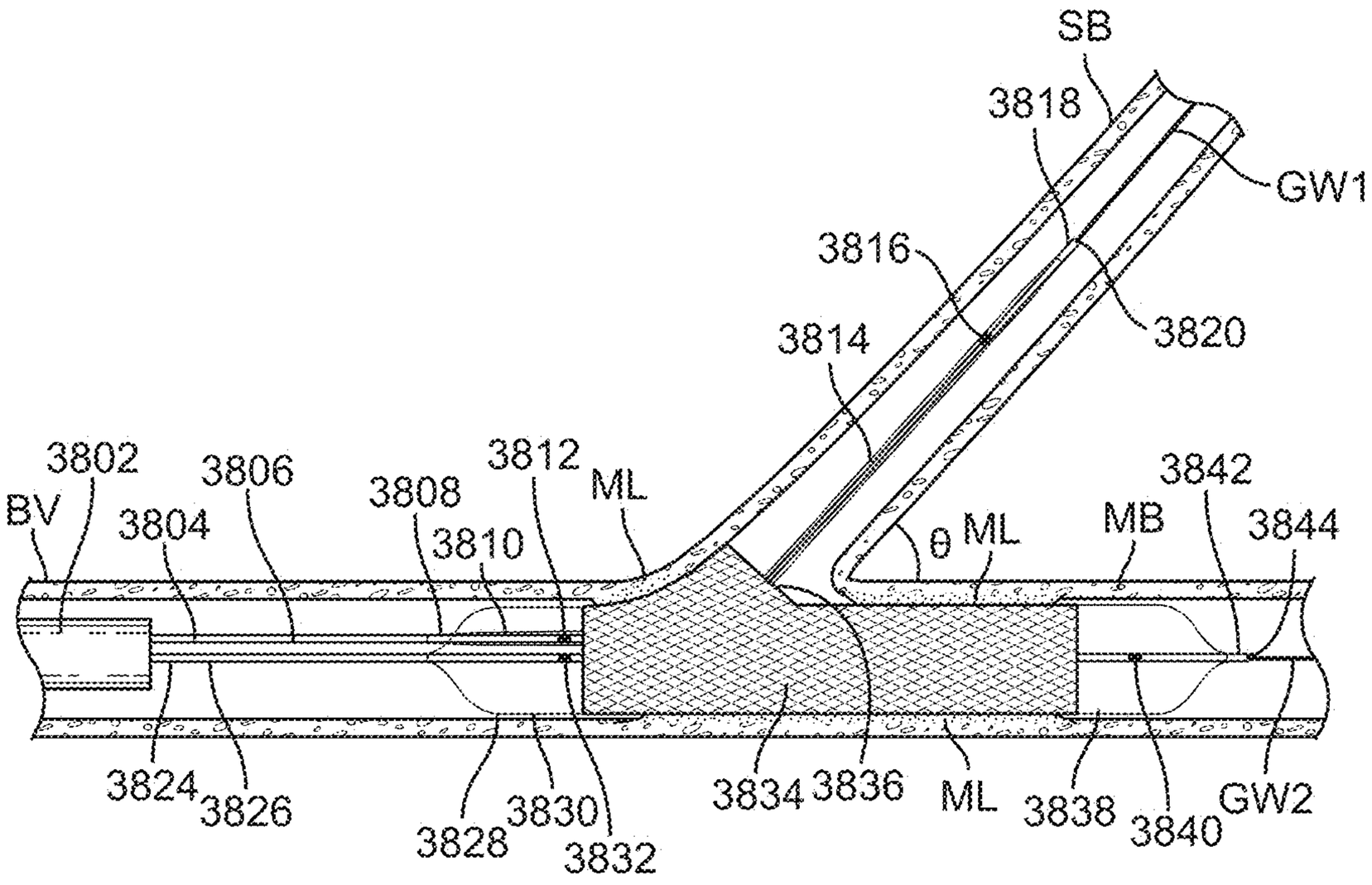

FIG. 38H

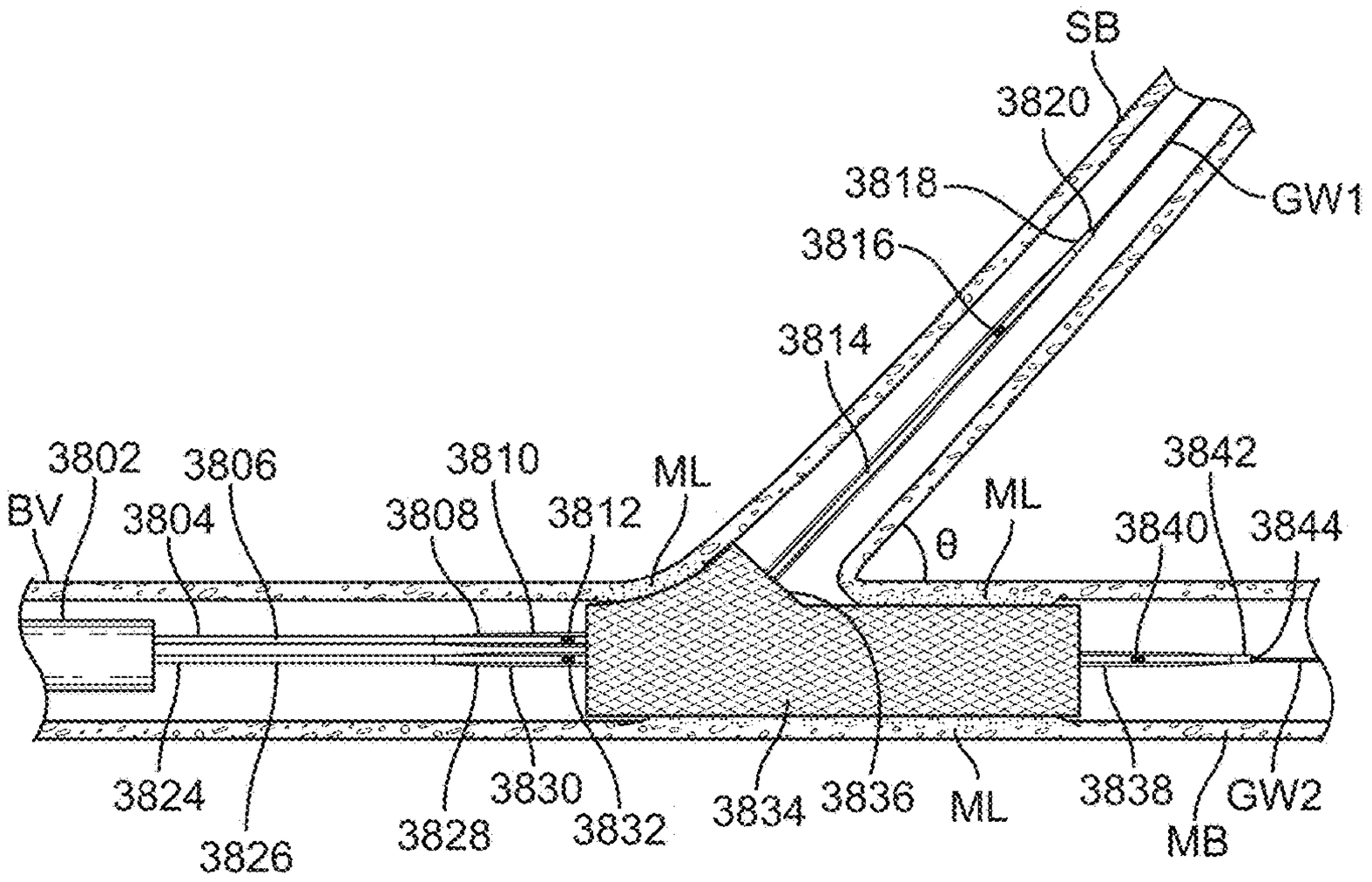

FIG. 38I

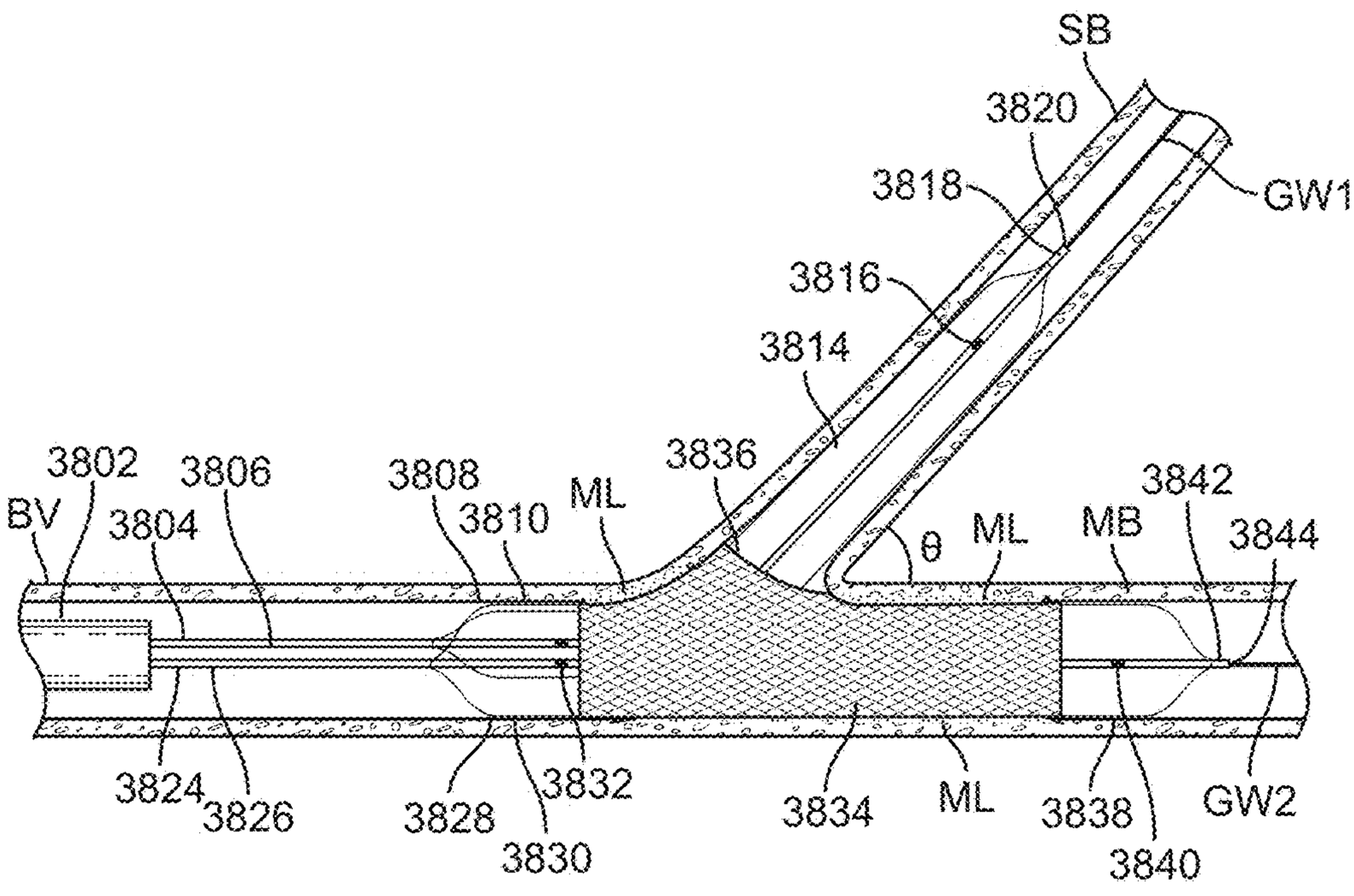

FIG. 38J

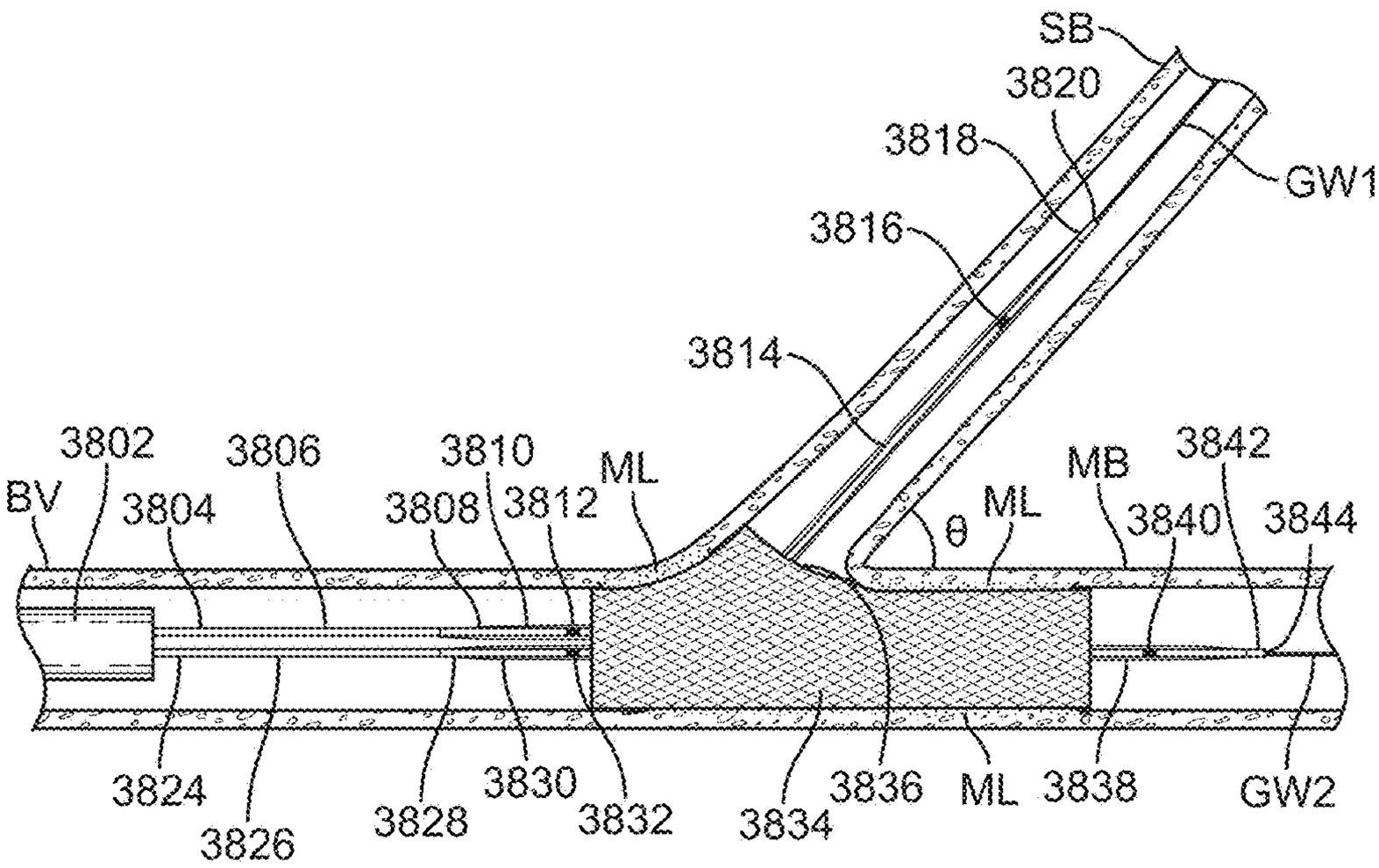

FIG. 38K

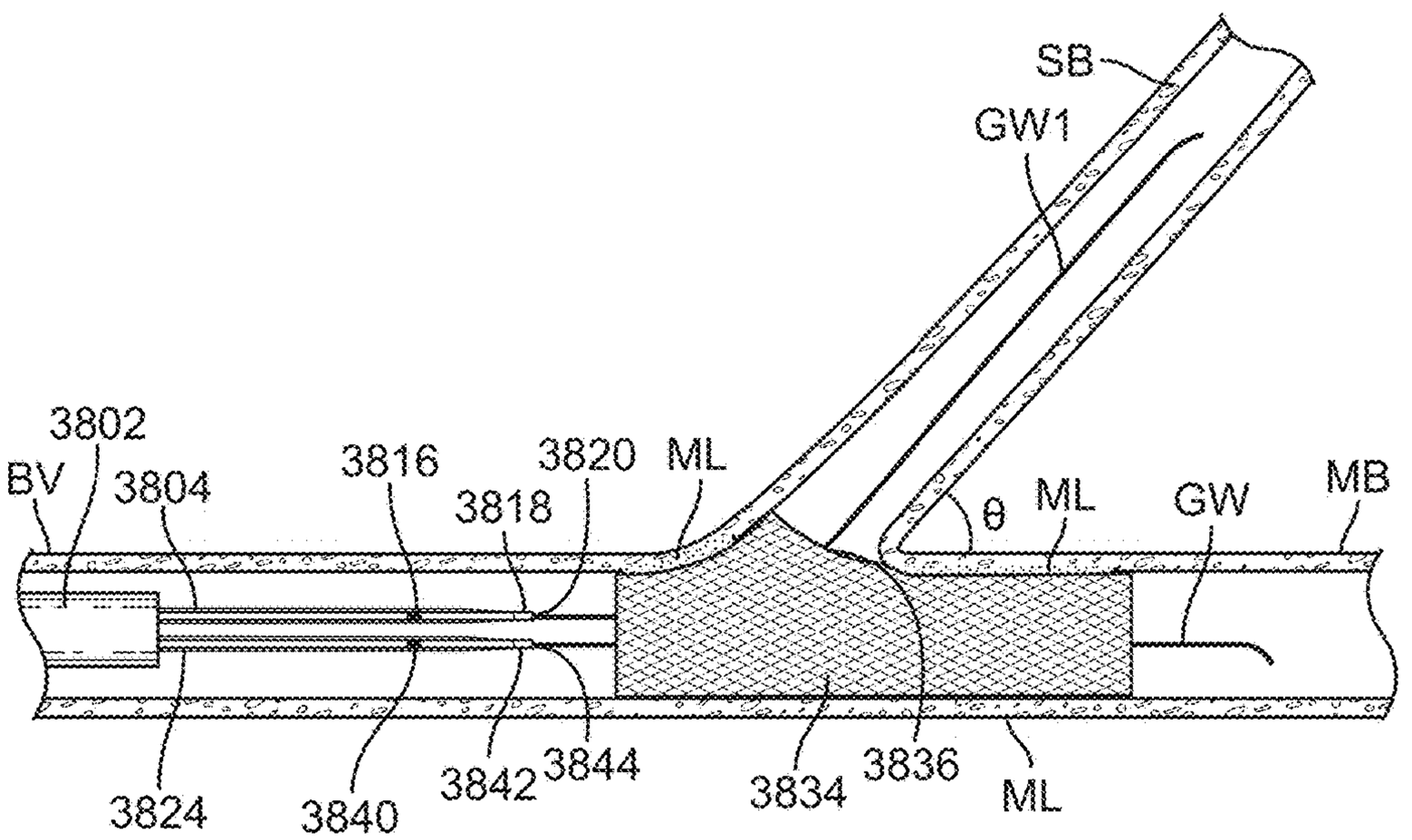

FIG. 38L

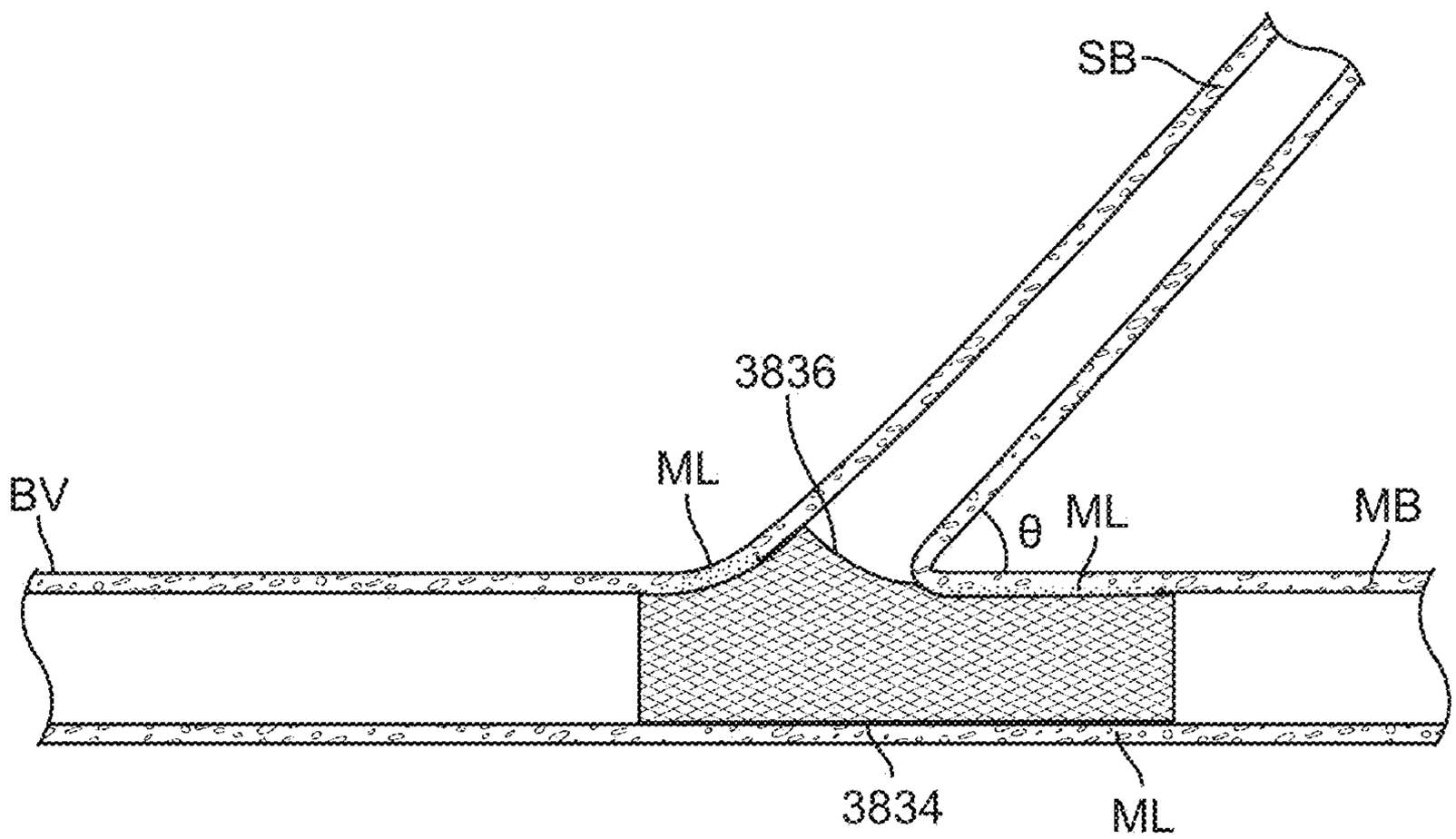

FIG. 38M

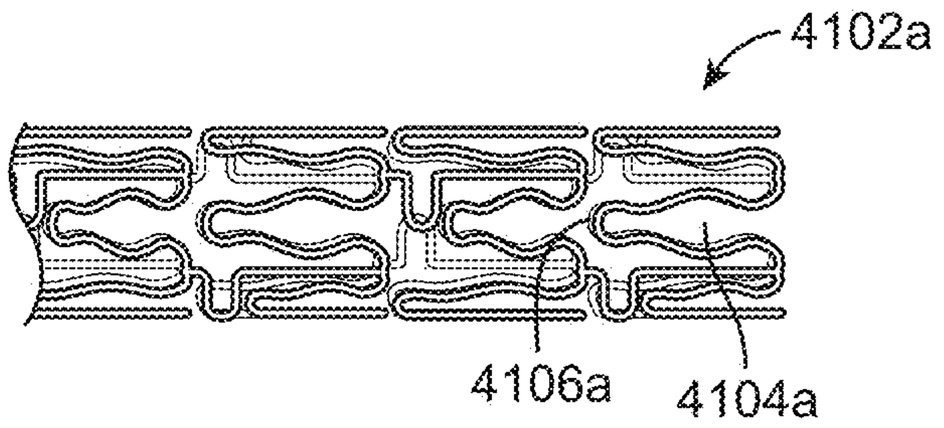

FIG. 39A

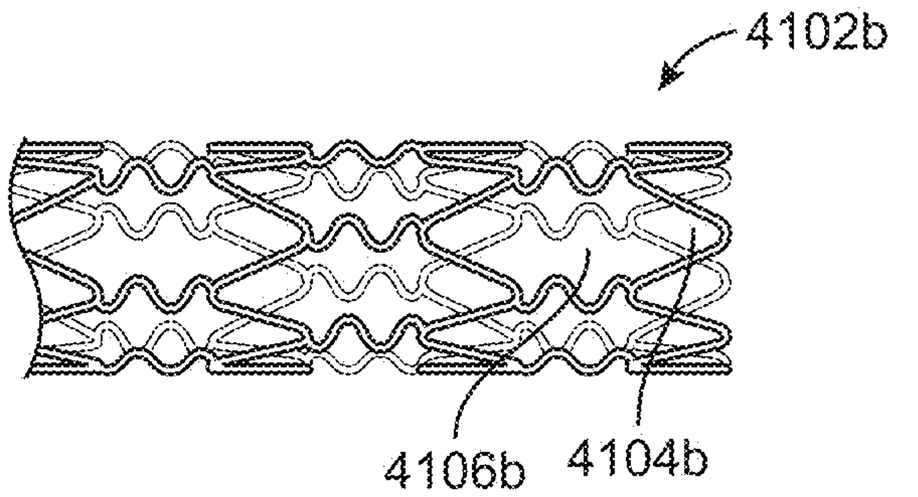

FIG. 39B

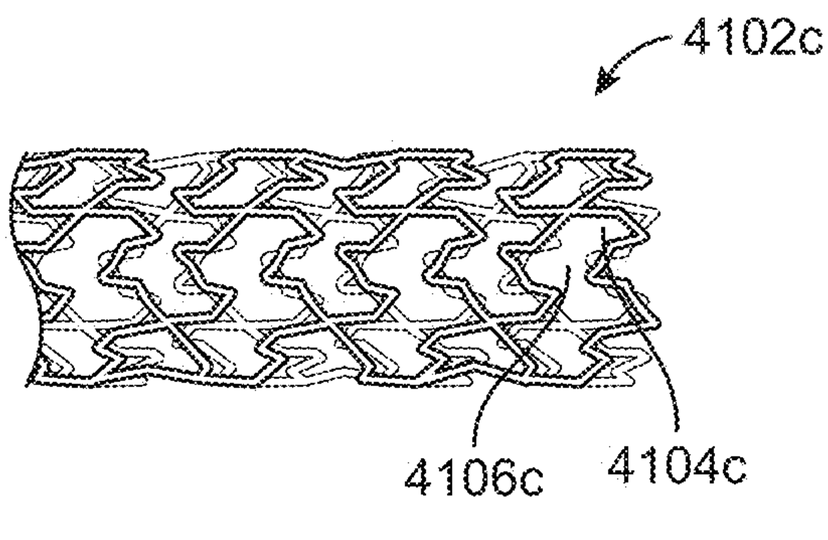

FIG. 39C

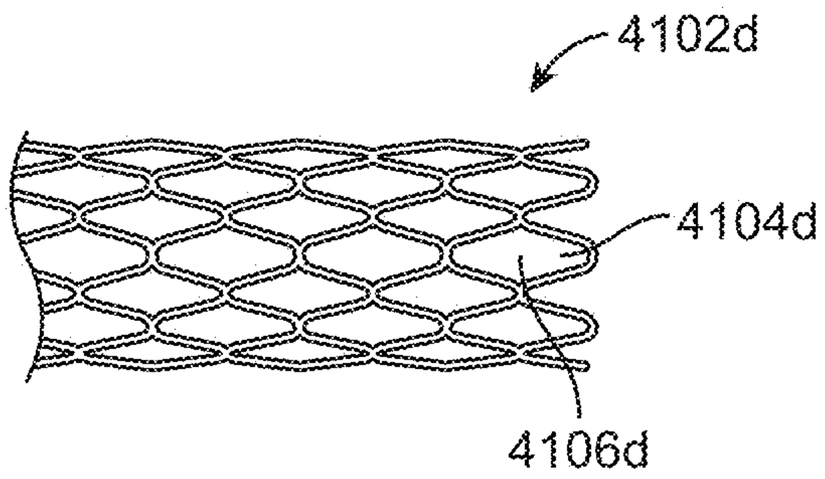

FIG. 39D

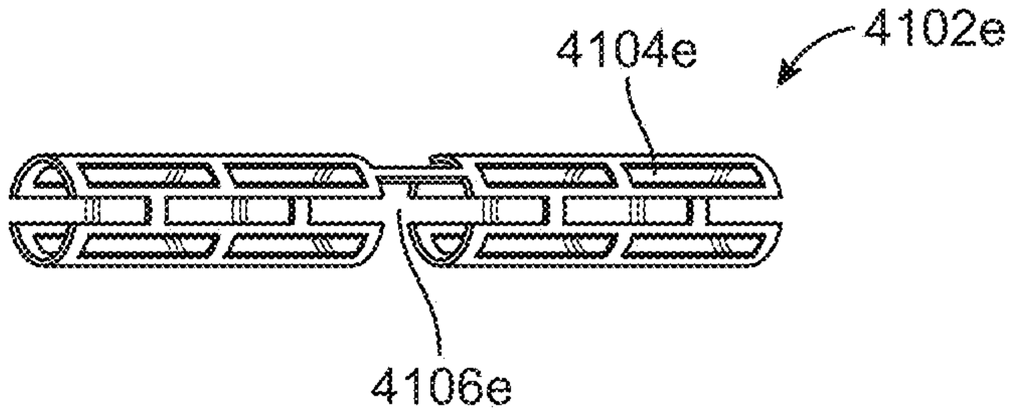

FIG. 39E

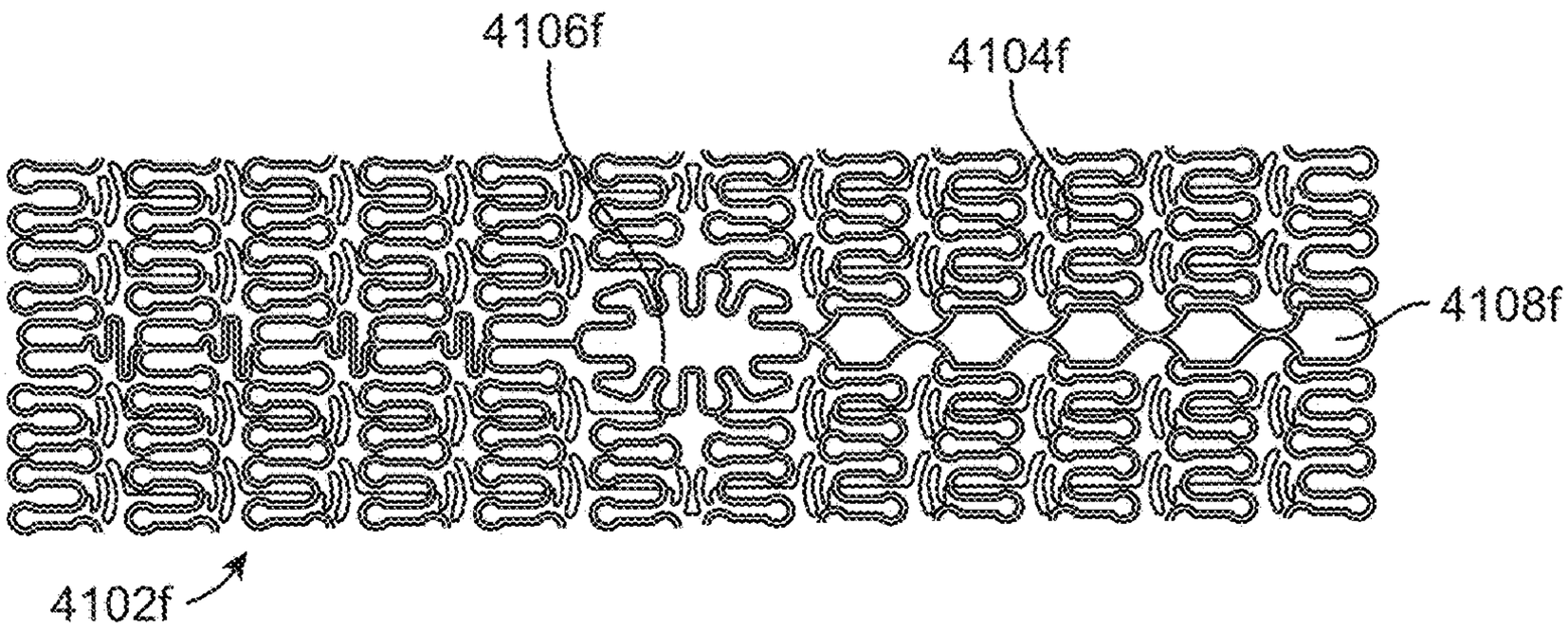

FIG. 39F

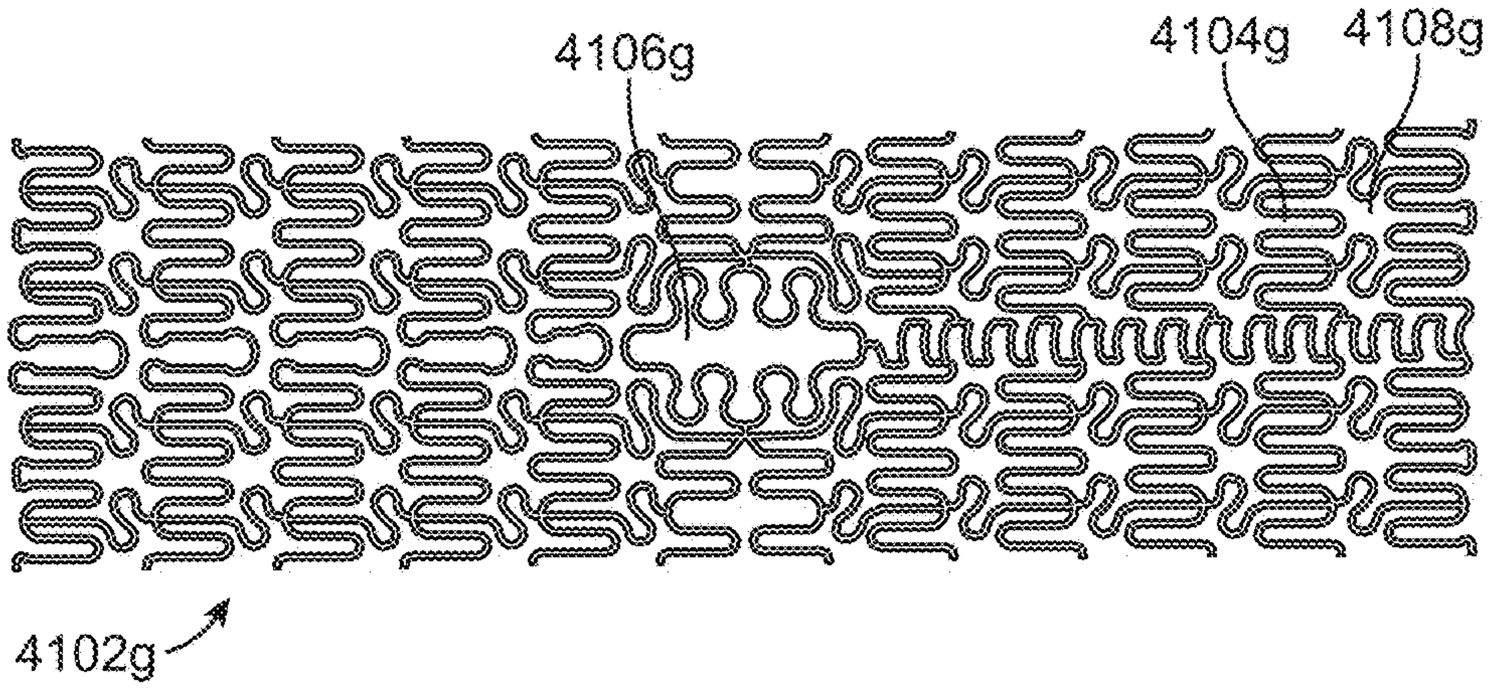

FIG. 39G

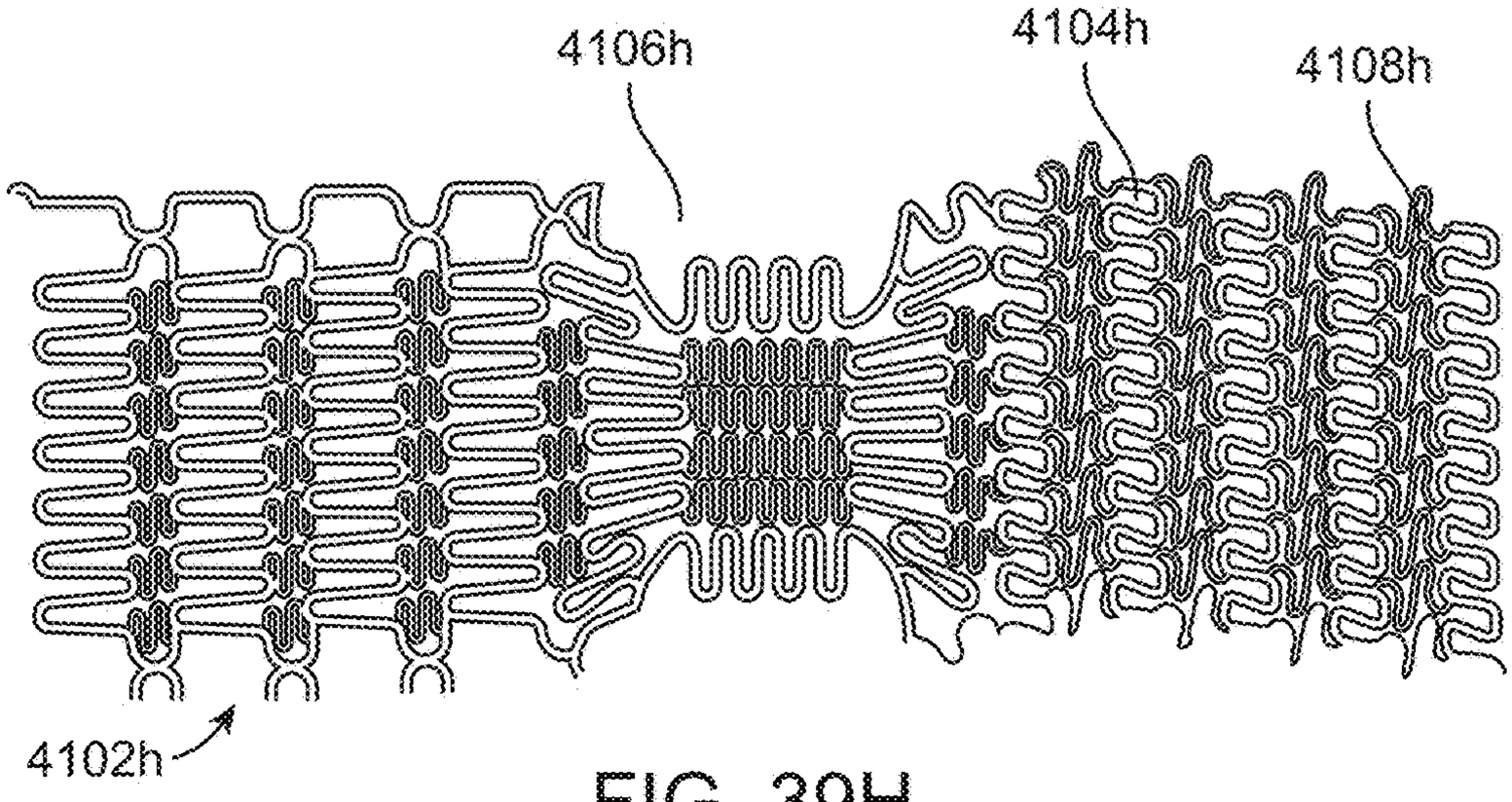

FIG. 39H

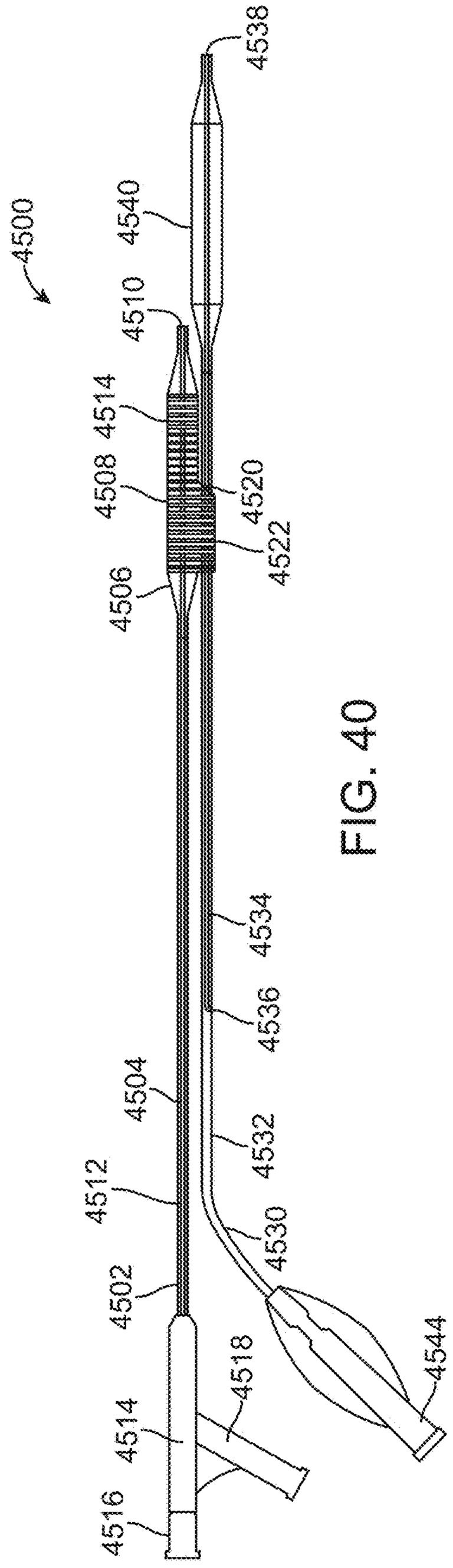
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FIG. 40

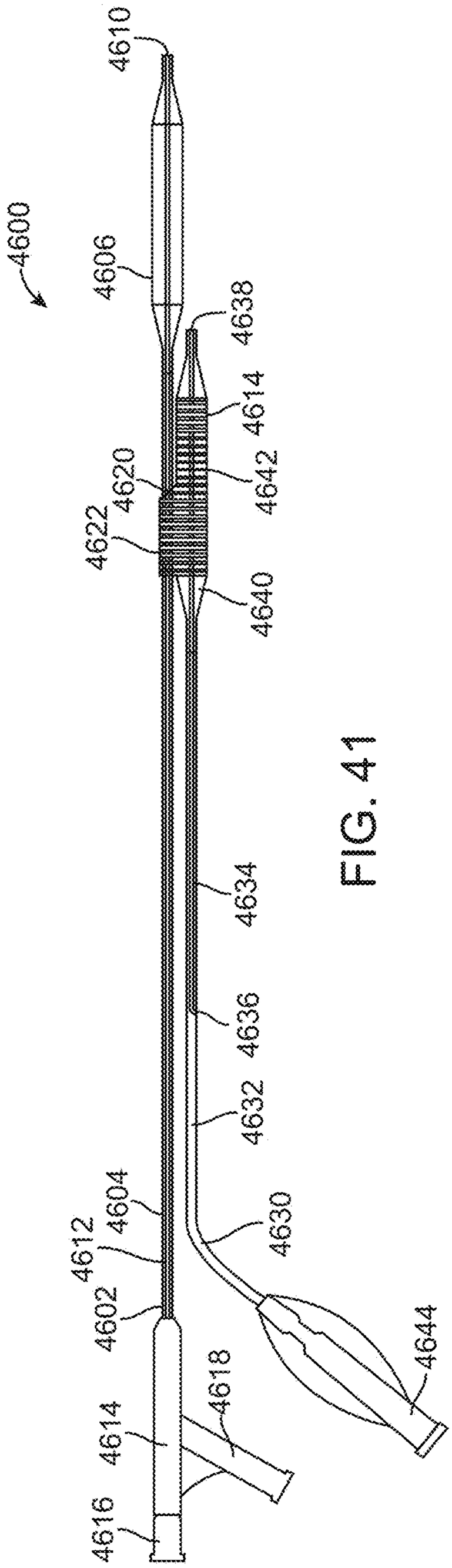
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FIG. 41

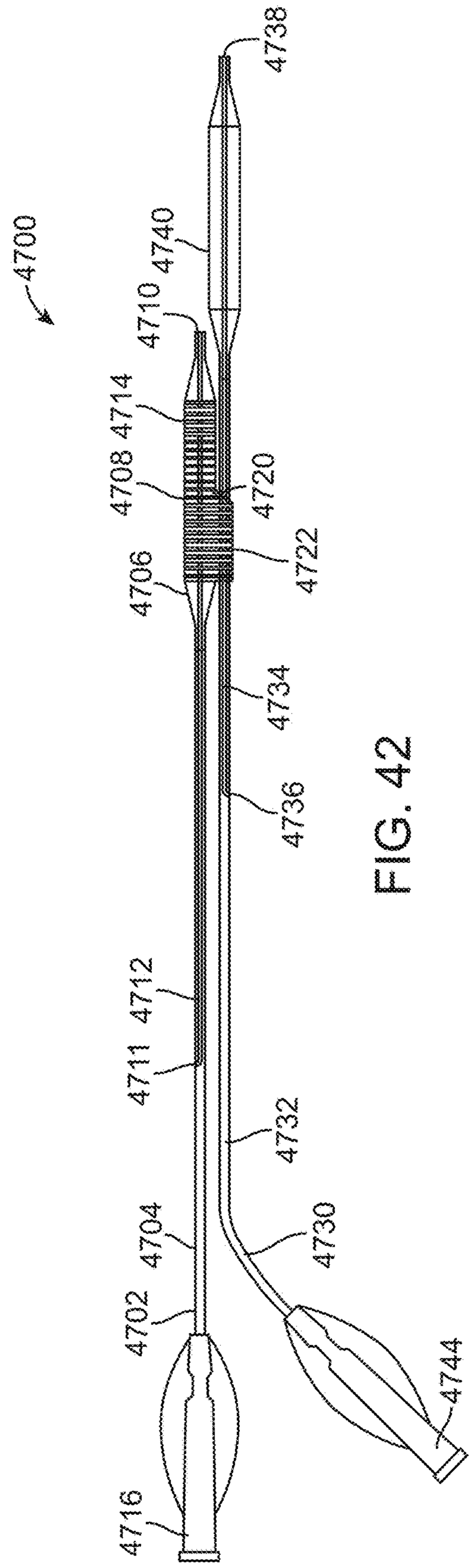
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FIG. 42

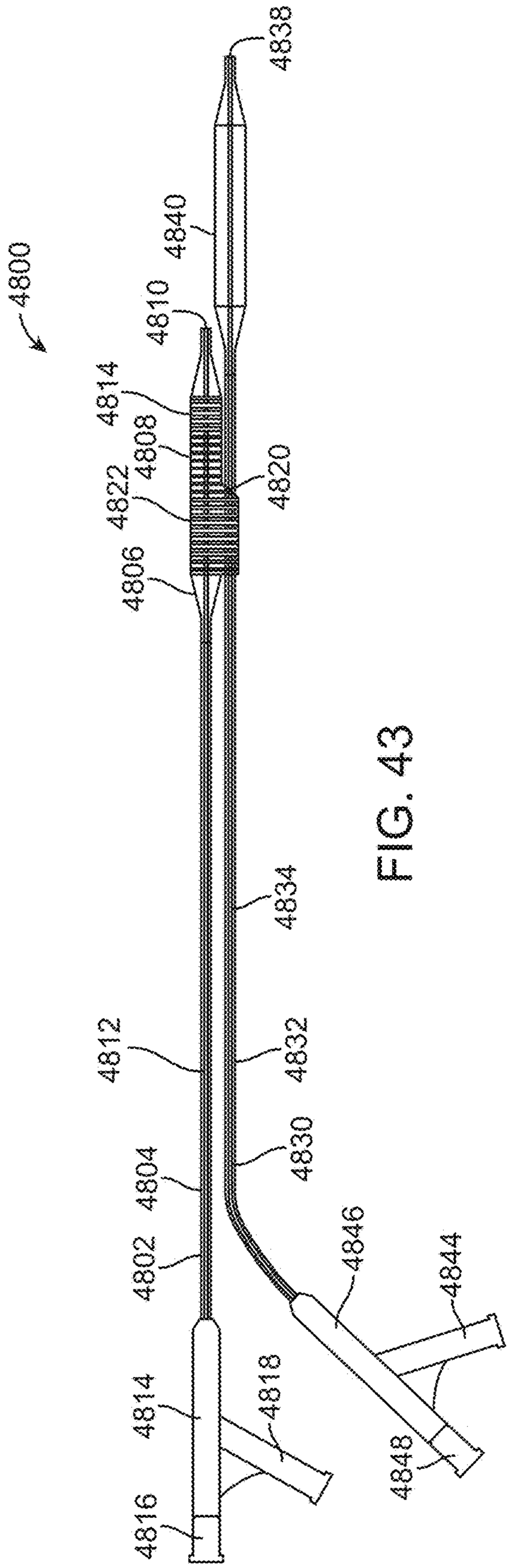
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FIG. 43

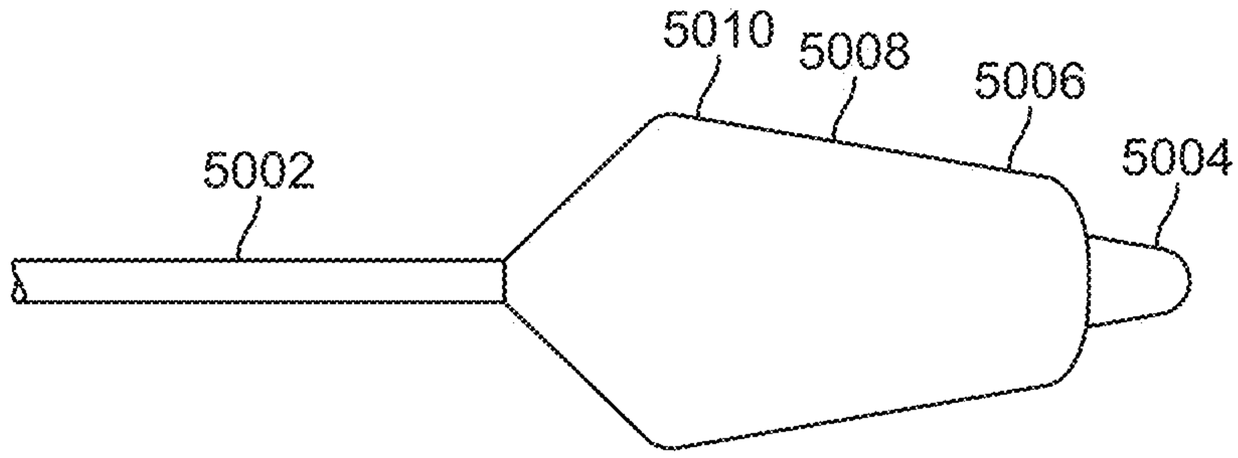

FIG. 44A

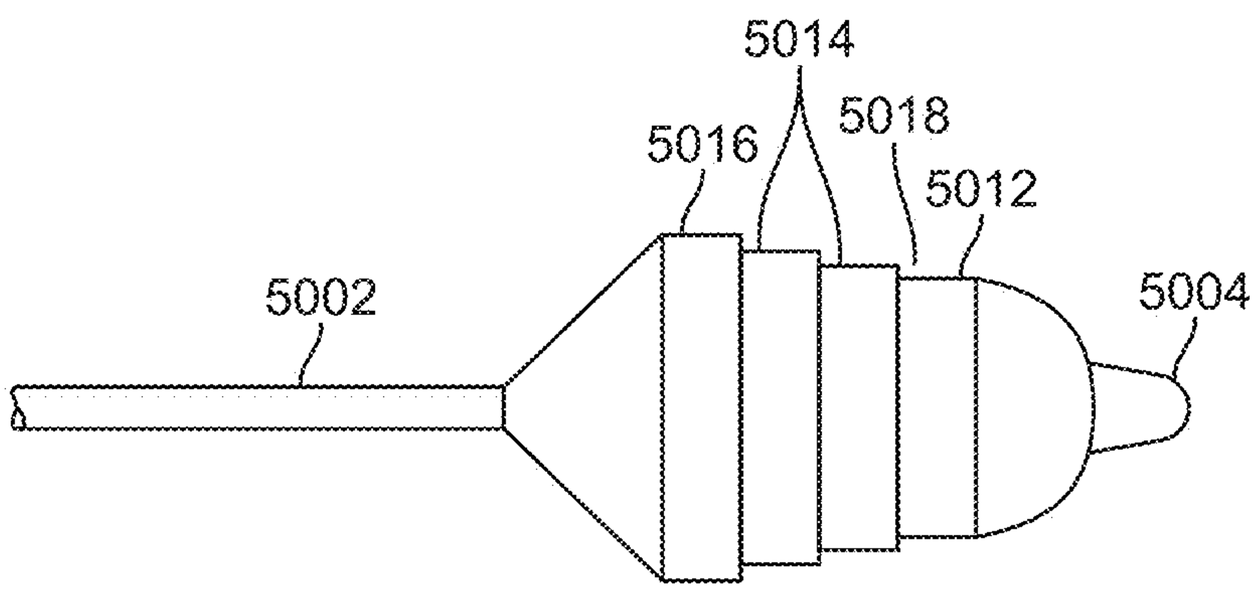

FIG. 44B

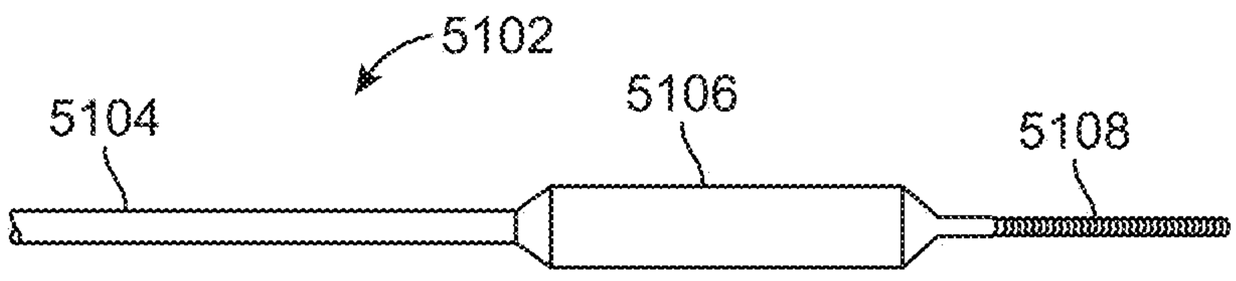

FIG. 45

METHODS AND SYSTEMS FOR TREATING A BIFURCATION WITH PROVISIONAL SIDE BRANCH STENTING

CROSS-REFERENCES TO RELATED APPLICATIONS

The present application is a Divisional of U.S. Ser. No. 13/071,198 filed Mar. 24, 2011 (Allowed); which claims the benefit of U.S. Provisional Appln. No. 61/317,114 filed Mar. 24, 2010, and is a Continuation-in-Part of PCT Appln. No. PCT/US2009/058505 filed Sep. 25, 2009; which claims the benefit of U.S. Provisional Appln. No. 61/194,346 filed Sep. 25, 2008; the entire contents of which are all incorporated herein by reference in their entirety for all purposes.

The present application is related to U.S. application Ser. No. 13/071,149 (Allowed); Ser. No. 13/071,251 (Allowed); Ser. No. 13/071,239 (Allowed); Ser. No. 13/071,183 (Allowed); and Ser. No. 13/071,162 (Allowed); all of which were filed on Mar. 24, 2011 and are incorporated herein by reference in their entirety for all purposes. The present application is also related to U.S. Provisional Appln. Nos. 61/317,105; 61/317,198; 61/317,121; and 61/317,130; all of which were filed on Mar. 24, 2010, and are incorporated herein by reference in their entirety for all purposes.

BACKGROUND OF THE INVENTION

The present invention relates to medical devices, and more particularly to stenting and treatment of bifurcated vessels. A stent is an implantable scaffold that is typically delivered percutaneously and deployed in a vein, artery, or other tubular body organ for treating an occlusion, stenosis, aneurysm, collapse, dissection, or weakened, diseased, or abnormally dilated vessel or vessel wall. The stent is radially expanded in situ, thereby expanding and/or supporting the vessel wall or body organ wall. In particular, stents are quite commonly implanted in the coronary, cardiac, pulmonary, neurovascular, peripheral vascular, renal, gastrointestinal and reproductive systems, and have been successfully implanted in the urinary tract, the bile duct, the esophagus, the tracheo-bronchial tree and the brain, to reinforce these body organs.

Stents are often used for improving angioplasty results by preventing elastic recoil and remodeling of the vessel wall and for treating dissections in blood vessel walls caused by balloon angioplasty of coronary arteries, as well as peripheral arteries, by pressing together the intimal flaps in the lumen at the site of the dissection. Conventional stents have been used for treating more complex vascular problems, such as lesions at or near bifurcation points in the vascular system, where a secondary artery branches out of a typically larger, main artery, with limited success rates.

Conventional stent technology is relatively well developed. Conventional stent designs typically feature a straight tubular, single type cellular structure, configuration, or pattern that is repetitive through translation along the longitudinal axis. In many stent designs, the repeating structure, configuration, or pattern has strut and connecting balloon catheter portions that can impede blood flow at vessel bifurcations.

Furthermore, the configuration of struts and connecting balloon catheter portions may obstruct the use of post-operative devices to treat a daughter vessel in the region of a vessel bifurcation. For example, deployment of a first stent in the mother lumen may prevent a physician from inserting a daughter stent through the ostium of a daughter vessel of

a vessel bifurcation in cases where treatment of the mother vessel is suboptimal because of displaced diseased tissue (for example, due to plaque shifting or "snow plowing"), occlusion, vessel spasm, dissection with or without intimal flaps, thrombosis, embolism, and/or other vascular diseases. A regular stent is designed in view of conflicting considerations of coverage versus access. For example, to promote coverage, the cell structure size of the stent may be minimized for optimally supporting a vessel wall, thereby preventing or reducing tissue prolapse. To promote access, the cell size may be maximized for providing accessibility of blood flow and of a potentially future implanted daughter stent to daughter vessels, thereby preventing "stent jailing," and minimizing the amount of implanted material. Regular stent design has typically compromised one consideration for the other in an attempt to address both. Problems the present inventors observed involving daughter jailing, fear of plaque shifting, total occlusion, and difficulty of the procedure are continuing to drive the present inventors' into the development of novel, delivery systems, which are easier, safer, and more reliable to use for treating the above-indicated variety of vascular disorders. Although conventional stents are routinely used in clinical procedures, clinical data shows that these stents are not capable of completely preventing in-stent restenosis (ISR) or restenosis caused by intimal hyperplasia. In-stent restenosis is the reoccurrence of the narrowing or blockage of an artery in the area covered by the stent following stent implantation. Patients treated with coronary stents can suffer from in-stent restenosis.

Many pharmacological attempts have been made to reduce the amount of restenosis caused by intimal hyperplasia. Many of these attempts have dealt with the systemic delivery of drugs via oral or intravascular introduction. However, success with the systemic approach has been limited.

Systemic delivery of drugs is inherently limited since it is difficult to achieve constant drug delivery to the afflicted region and since systemically administered drugs often cycle through concentration peaks and valleys, resulting in time periods of toxicity and ineffectiveness. Therefore, to be effective, anti-restenosis drugs should be delivered in a localized manner. One approach for localized drug delivery utilizes stents as delivery vehicles. For example, stents seeded with transfected endothelial cells expressing bacterial betagalactosidase or human tissue-type plasminogen activator were utilized as therapeutic protein delivery vehicles. See, e.g., Dichek, D. A. et al., "Seeding of Intravascular Stents With Genetically Engineered Endothelial Cells," Circulation, 80:1347-1353 (1989). U.S. Pat. No. 5,679,400, International Patent Publication No. WO 91/12779, entitled "Intraluminal Drug Eluting Prosthesis," and International Patent Publication No. WO 90/13332, entitled "Stent With Sustained Drug Delivery" disclose stent devices capable of delivering antiplatelet agents, anticoagulant agents, antimigratory agents, antimetabolic agents, and other anti-restenosis drugs. U.S. Pat. Nos. 6,273,913; 6,383,215; 6,258,121; 6,231,600; 5,837,008; 5,824,048; 5,679,400; and 5,609,629 teach stents coated with various pharmaceutical agents such as Rapamycin, 17-beta-estradiol, Taxol and Dexamethasone. This and all other referenced patents are incorporated herein by reference in their entirety. Furthermore, where a definition or use of a term in a reference, which is incorporated by reference herein is inconsistent or contrary to the definition of that term pro-

vided herein, the definition of that term provided herein applies and the definition of that term in the reference does not apply.

Therefore, given the challenges of current stent technology, a need exists for improved stent delivery systems and methods, particularly for treating bifurcated vessels. At least some of these objectives will be met by the present invention.

BRIEF SUMMARY OF THE INVENTION

The present invention relates to methods and delivery systems used to deliver stents in a bifurcated vessel. Embodiments may be configured to stent at least a portion of a mother vessel and a portion of a daughter vessel.

In a first aspect of the present invention, a system for treating a bifurcation comprises a first delivery catheter and a second delivery catheter. The first delivery catheter comprises a first elongate shaft with proximal and distal ends, and a first expandable member adjacent the distal end of the first elongate shaft. The second delivery catheter comprises a second elongate shaft with proximal and distal ends, a second expandable member adjacent the distal end of the second elongate shaft, and a radially expandable stent disposed over the second expandable member. The stent comprises a sidewall having a side hole therethrough, and the stent also has a collapsed configuration and an expanded configuration. In the collapsed configuration the stent is suitable for delivery to the bifurcation, and in the expanded configuration the stent supports a vessel wall. A first portion of the first elongate shaft is disposed under a proximal portion of the stent. Also, the first elongate shaft passes through the side hole so that a second portion of the first elongate shaft is disposed over a distal portion of the stent. The first elongate shaft is axially slidable relative to the second elongate shaft while the stent is in the collapsed configuration.

In preferred embodiments, at least one stent has a sidewall with a side hole or aperture extending therethrough, and a portion of a delivery catheter may pass through the side hole. However, this is not intended to be limiting, and in any of the embodiments disclosed herein, one of skill in the art will appreciate that the stent may have another exit point. Thus the delivery catheter may pass through the exit point, whether it is a side hole in a side wall of the stent, or disposed in another portion of the stent.

The first expandable member and the second expandable member may be independently expandable of one another. The first or the second expandable member may comprise a balloon. Each of the first and the second delivery catheters may comprise an inflation lumen and/or a guidewire lumen. The first delivery catheter may comprise a distal guidewire opening in the distal end of the first elongate shaft, and a proximal guidewire opening. The proximal guidewire opening may be spaced closer to the distal guidewire opening than the proximal end of the first elongate shaft. In other embodiments, the proximal guidewire opening may be closer to the proximal end of the first elongate shaft than the distal guidewire opening. The guidewire lumen in the first delivery catheter may be configured to slidably receive a guidewire, and the guidewire lumen may extend from the distal guidewire opening to the proximal guidewire opening.

The second delivery catheter may comprise a distal guidewire opening in the distal end of the second elongate shaft, and a proximal guidewire opening. The proximal guidewire opening may be spaced closer to the distal guidewire opening than the proximal end of the second elongate shaft. In other embodiments, the proximal guidewire opening may be closer to the proximal end of the second elongate shaft than the distal guidewire opening. The guidewire lumen in the second delivery catheter may be configured to slidably receive a guidewire, and the guidewire lumen may extend from the distal guidewire opening to the proximal guidewire opening.

The first expandable member may be axially spaced apart from the second expandable member such that the first expandable member is distal to the second expandable member. The distal expandable member may have a cross-sectional profile that is smaller than the cross-sectional profile of the other expandable member. The first or the second expandable member comprises a working length and the working length may comprise a tapered region such that a proximal portion of the working length has a diameter greater than a distal portion of the working length.

One of the first elongate shaft or the second elongate shaft may comprise a region having a guidewire lumen, an inflation lumen, and an exchange lumen. The other elongate shaft may be slidably disposed in the exchange lumen. The expandable member on the other elongate shaft may be axially spaced apart from the first elongate shaft having the exchange lumen such that the expandable member on the other shaft is distal to the expandable member on the elongate shaft with the exchange lumen. The system may comprise a capture tube having a proximal end, a distal end, a longitudinal axis, and a central channel extending therebetween. The first elongate shaft and the second elongate shaft may be slidably disposed in the central channel. The capture tube may prevent the first elongate shaft from tangling with the second elongate shaft. The capture tube may comprise a perforated region extending along the longitudinal axis, extending at least partially between the proximal and distal ends of the capture tube so that the capture tube may be peeled away from the first and second elongate shafts. The capture tube may also comprise a locking mechanism for releasably holding the first elongate shaft and the second elongate shaft.

One of the first elongate shaft or the second elongate shaft may comprise a snap fitting configured to receive and retain the other elongate shaft. The other elongate shaft may be slidably movable axially through the snap fitting, and the expandable member on the other elongate shaft may be axially spaced apart from the elongate shaft having the snap fitting such that the expandable member on the other elongate shaft is distal to the expandable member on the elongate shaft with the snap fitting. The system may comprise a polymer sleeve having a proximal end, a distal end, a longitudinal axis, and a central channel extending therebetween. The first elongate shaft and the second elongate shaft may be slidably disposed in the central channel. The polymer sleeve may prevent the first elongate shaft from tangling with the second elongate shaft.

The stent may be balloon expandable, self-expanding, or a combination thereof. The stent may be non-uniformly crimped to the second expandable member. A therapeutic agent may be disposed on the radially expandable stent or on one of the first or the second expandable members, and the agent may be adapted to being eluted therefrom. The therapeutic agent may comprise an anti-restenosis agent.

The first elongate shaft may comprise a radiopaque marker disposed thereon, and the second elongate shaft may comprise a radiopaque marker disposed thereon. When the first radiopaque marker is aligned with the second radiopaque marker a working portion of the first expandable member may be aligned with a working portion of the

second expandable member. A portion of the first expandable member may be disposed under the stent such that expansion of the first expandable member will also expand a proximal portion of the stent while a distal portion of the stent remains unexpanded. Either the first expandable member or the second expandable member may be differentially expandable such that a proximal portion of the differentially expandable member has a larger diameter than a distal portion of the differentially expandable member. The stent may also be differentially expandable such that in the expanded configuration a first portion of the stent has a larger diameter than a second portion of the stent.

The first delivery catheter may comprise a first guidewire lumen extending at least partially between the proximal and distal ends of the first elongate shaft. The system may further comprise a first guidewire that is slidably positioned in the first guidewire lumen. The second delivery catheter may comprise a second guidewire lumen extending at least partially between the proximal and distal ends of the second elongate shaft. The system may further comprise a second guidewire that is slidably positioned in the second guidewire lumen. A guidewire may be fixedly attached to a distal end of the first elongate shaft or the second elongate shaft.

In another aspect of the present invention, a method of treating a bifurcated vessel comprises providing a first delivery catheter and a second delivery catheter. The first delivery catheter comprises a first elongate shaft, and a first expandable member. The second delivery catheter comprises a second elongate shaft, a second expandable member, and a stent having a side hole, the stent disposed over the second expandable member. A portion of the first elongate shaft is disposed under the stent and the first elongate shaft exits the side hole in the stent. The first expandable member is distal to the second expandable member. Both the first and second delivery catheters are advanced through a main branch vessel having a lesion to a bifurcation in the main branch. The bifurcation comprises a side branch vessel extending from the main branch vessel. The stent is advanced until the stent is in the main branch and traverses the main branch lesion and the side hole is adjacent the ostium to the side branch. The first expandable member is disposed in the side branch. The first elongate shaft is proximally retracted under a portion of the stent until the first expandable member is disposed under the stent while another portion of the first expandable member is disposed in the side branch. The first expandable member is radially expanded thereby expanding a proximal portion of the stent into engagement with the lesion in the main branch and expanding the side hole while a distal portion of the stent remains unexpanded. The second expandable member is radially expanded, thereby expanding a distal portion of the stent into engagement with the lesion in the main branch and the wall of the main branch.

The advancing step may comprise advancing both the first and the second delivery catheters until resistance to further advancement is felt by an operator. The resistance may be provided by separation of the first elongate shaft from the second elongate shaft as both shafts are advanced against a wall formed between the main branch and the side branch.

The first delivery catheter may comprise a first radiopaque marker disposed adjacent a proximal region of the first expandable member, and the second delivery catheter may comprise a second radiopaque marker disposed adjacent a proximal region of the second expandable member. The retracting step may comprise retracting the first elongate shaft until the first radiopaque marker is aligned with the second radiopaque marker. The second elongate shaft may comprise an exchange lumen, and the retracting may comprise slidably retracting the first elongate shaft through the exchange lumen. The first and the second elongate shafts may be disposed in a central channel of a capture tube, and the retracting may comprise slidably retracting the first elongate shaft through the central channel. The capture tube may comprise a perforated region, and the method may further comprise separating the perforated region and peeling the capture tube away from the first and the second elongate shafts. The second elongate shaft may comprise a snap fitting configured to receive and retain the first elongate shaft. The retracting may comprise slidably retracting the first elongate shaft along the snap fitting. The first and the second elongate shaft may be disposed in a polymer tube having a central channel therethrough, and the retracting may comprise slidably retracting the first elongate shaft through the central channel.

The first expandable member may comprise a balloon, and the expanding of the first expandable member may comprise inflating the balloon. The method may further comprise contracting the first expandable member after expansion thereof and prior to the expansion of the second expandable member. The expanding of the stent may comprise differentially expanding the stent so that a proximal region of the expanded stent may have a larger diameter than a distal region of the expanded stent. The second expandable member may comprise a balloon, and the expanding step may comprise inflating the balloon.

The method may further comprise simultaneously expanding the first and the second expandable members into engagement with one another thereby ensuring engagement of the stent with the lesion in the main branch and walls of the main branch. This may also ensure alignment of the side hole in the stent with the side branch. The main branch and the side branch may have substantially similar diameters. The method may further comprise eluting a therapeutic agent from the stent or the first expandable member or the second expandable member into the main branch lesion. The therapeutic agent may comprise an anti-restenosis agent.

These and other embodiments are described in further detail in the following description related to the appended drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A-**1**B illustrate an exemplary embodiment of a system having an over-the-wire mother catheter and a rapid exchange daughter catheter.

FIGS. **2**A-**2**B illustrate an exemplary embodiment of a system having an over-the-wire daughter catheter and a rapid exchange mother catheter.

FIGS. **3**A-**3**B illustrate an exemplary embodiment of a system having a rapid exchange mother catheter and a rapid exchange daughter catheter.

FIGS. **4**A-**4**B illustrate an exemplary embodiment of a system having an over-the-wire mother catheter and an over-the-wire daughter catheter.

FIGS. **5**A-**5**B illustrate another exemplary embodiment of a system having a capture tube, an over-the-wire mother catheter, and a rapid exchange daughter catheter.

FIGS. **6**A-**6**B illustrate another exemplary embodiment of a system having a capture tube, an over-the-wire daughter catheter, and a rapid exchange mother catheter.

FIGS. **7**A-**7**B illustrate another exemplary embodiment of a system having a capture tube, a rapid exchange mother catheter, and a rapid exchange daughter catheter.

FIGS. **8**A-**8**B illustrate another exemplary embodiment of a system having a capture tube, an over-the-wire mother catheter, and an over-the-wire daughter catheter.

FIGS. **9**A-**9**B illustrate yet another exemplary embodiment of a system having a removable capture tube, an over-the-wire mother catheter and a rapid exchange daughter catheter.

FIGS. **10**A-**10**B illustrate yet other exemplary embodiment of a system having a removable capture tube, an over-the-wire daughter catheter and a rapid exchange mother catheter.

FIGS. **11**A-**11**B illustrate yet another exemplary embodiment of a system having a removable capture tube, a rapid exchange mother catheter and a rapid exchange daughter catheter.

FIGS. **12**A-**12**B illustrate yet another exemplary embodiment of a system having a removable capture tube, an over-the-wire mother catheter and an over-the-wire daughter catheter.

FIGS. **13**A-**13**C illustrate still another exemplary embodiment of a system having a snap fitting, an over-the-wire mother catheter and a rapid exchange daughter catheter.

FIGS. **14**A-**14**C illustrate still another exemplary embodiment of a system having a snap fitting, an over-the-wire daughter catheter and a rapid exchange mother catheter.

FIGS. **15**A-**15**C illustrate still another exemplary embodiment of a system having a snap fitting, a rapid exchange mother catheter and a rapid exchange daughter catheter.

FIGS. **16**A-**16**C illustrate still another exemplary embodiment of a system having a snap fitting, an over-the-wire mother catheter and an over-the-wire daughter catheter.

FIGS. **17**A-**17**C illustrate another exemplary embodiment of a system having a snap fitting, an over-the-wire mother catheter and a rapid exchange daughter catheter.

FIGS. **18**A-**18**C illustrate another exemplary embodiment of a system having a snap fitting, an over-the-wire daughter catheter and a rapid exchange mother catheter.

FIGS. **19**A-**19**C illustrate another exemplary embodiment of a system having a snap fitting, a rapid exchange mother catheter and a rapid exchange daughter catheter.

FIGS. **20**A-**20**C illustrate another exemplary embodiment of a system having a snap fitting, an over-the-wire mother catheter and an over-the-wire daughter catheter.

FIGS. **21**A-**21**B illustrate yet another exemplary embodiment of a system having an over-the-wire mother catheter and a rapid exchange daughter catheter.

FIGS. **22**A-**22**B illustrate yet another exemplary embodiment of a system having an over-the-wire daughter catheter and a rapid exchange mother catheter.

FIGS. **23**A-**23**B illustrate yet another exemplary embodiment of a system having a rapid exchange mother catheter and a rapid exchange daughter catheter.

FIGS. **24**A-**24**B illustrate yet another exemplary embodiment of a system having an over-the-wire mother catheter and an over-the-wire daughter catheter.

FIGS. **25**A-**25**B, **26**A-**26**B, **27**A-**27**B, **28**A-**28**B, **29**A-**29**B, and **30**A-**30**B illustrate an exemplary method of treating a bifurcation.

FIG. **31** illustrates an exemplary embodiment of a stent.

FIG. **32** illustrates an exemplary embodiment of a system having a mother catheter and a daughter catheter.

FIG. **33** highlights the distal portion of the system illustrated in FIG. **32**.

FIG. **34** illustrates alignment of the stents in FIGS. **32-33**.

FIG. **35** illustrates a cross-section of a stent crimped over a mother catheter and a daughter catheter.

FIG. **36** illustrates a stent disposed over a mother catheter and a daughter catheter.

FIG. **37** illustrates a stent disposed over a mother catheter and a daughter catheter, and a stent disposed over the daughter catheter.

FIGS. **38**A-**38**M illustrate an exemplary method of treating a bifurcation.

FIGS. **39**A-**39**H illustrate various stents may be used to treat bifurcations.

FIGS. **40-43** illustrate exemplary embodiments of another stent delivery system.

FIGS. **44**A-**44**B illustrate exemplary embodiments of several balloon configurations.

FIG. **45** illustrates a balloon catheter having a fixed guidewire.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to delivery systems for delivery of stents to vessel bifurcations having a main branch and a side branch, and is generally configured to at least partially cover a portion of a the side branch as well as a portion of the main branch. However, this is not intended to be limiting, and one of skill in the art will appreciate that the devices and methods described herein may be used for treating other regions of the body.

The scientific community is slowly moving away from a main branch vs. side branch model and nomenclature. It is now well accepted that a "mother" vessel bifurcates into two "daughter vessels," the two vessels that are anatomically after the carina. The vessel that appears to be the continuation of the mother vessel is usually less angulated. The other vessel may is frequently smaller in diameter and may be commonly referred to as the side branch, or a daughter vessel. Therefore, in this specification, the terms "main branch," "trunk," or "mother vessel" may be used interchangeably. Also in this specification, the terms "side branch vessel" and "daughter vessel" may also be used interchangeably. The terms "main branch stent," "trunk stent," or "mother stent" are interchangeable, and the term "side branch stent" is also interchangeable with the term "daughter stent." In the case where a main branch vessel bifurcates into two equally sized branches, one of the branches may still be considered to be the main branch or mother vessel, and the other branch may be considered a side branch or daughter vessel.

A variety of catheter designs may be employed to deploy and position the mother and daughter stents. Such catheters may be used in connection with multiple guidewires that terminate in the mother and daughter vessels. These guidewires may be used to facilitate introduction of the catheter, any angioplasty balloons, any stents, and/or to properly orient the stent or balloon within the vessel.

In general, the methods disclosed herein may utilize a catheter system comprising a catheter body having a mother vessel guidewire lumen and a daughter vessel balloon that is independently operable and coupled to the catheter body. The daughter balloon catheter portion has a daughter vessel guidewire lumen. The catheter system further includes a mother catheter balloon, and a stent is disposed over the balloon. The daughter catheter portion extends into the proximal opening of the mother stent and exits the mother stent through a side passage of the mother stent.

According to one method, a mother vessel guidewire is inserted into the mother vessel until a distal end of the mother vessel guidewire passes beyond the ostium of the

daughter vessel, and a daughter vessel guidewire is inserted into the mother vessel until a distal end of the daughter vessel guidewire passes into the daughter vessel. To prevent the crossing of guidewires, the two vessels are wired through a guidewire catheter with two lumens to keep the guidewires separate and untangled.

The guidewire catheter is then removed and a wire separator is placed on the wires to keep the guidewires unwrapped. The catheter system is then advanced over the mother and daughter vessel guidewires, with the mother and daughter vessel catheters passing over the mother vessel guidewire and the daughter vessel guidewire. The catheter system is advanced on both wires with the daughter vessel balloon catheter portion distal to the mother balloon catheter portion, leading the system. As the catheter system advances over the wires, the daughter vessel balloon will enter the daughter vessel and may be positioned after or simultaneously with placement of the mother vessel balloon. The mother balloon catheter portion of the catheter system is then advanced distally as far as it can be advanced where it is stopped by the carina. It cannot be advanced beyond the bifurcation site because the tension of the daughter catheter on the mother stent will prevent the mother catheter from moving distally. At this time the distal portion of the mother stent is beyond the carina in the mother vessel and cannot be advanced any further. This method facilitates advancement of the catheter system to the bifurcation, which may be necessary for tortuous or calcified coronaries. Once the catheter system is in place the daughter vessel balloon catheter portion is then pulled back relative to the mother catheter so that the proximal part of the daughter balloon is partially within the mother stent. Alignment can be performed with radiopaque markers, in that the proximal markers on the two balloons are next to each other. The operator can then gently push the catheter system distal to maximize apposition to the carina. The daughter balloon which is now partially under the mother stent is then inflated to ensure proper alignment of the mother stent. The daughter balloon may also have a stent on its distal portion, which would result in the proximal portion of the mother stent and the daughter stent to expand simultaneously. The daughter balloon is then deflated.

The mother balloon is then inflated which deploys the mother stent. Kissing, reinflation, of the two balloons is performed if necessary or for shifting plaque. The catheter system may be removed while the wires remain in place. In this embodiment, or any of the other embodiments disclosed herein, an angioplasty catheter may be used to predilate the vessel and lesion prior to stenting. In some embodiments, primary stenting is employed where the stent is deployed without the predilation. The two vessels may be angioplastied separately if predilatation is indicated on occasion.

In an alternative method, the mother catheter can be mounted on the daughter vessel guidewire and the daughter catheter can be mounted on the mother vessel guidewire. In daughter vessels with a high degree of angularity, for example, when the bifurcation angle is greater than about 60-70°, the friction between catheters is lower when the operator needs to draw the daughter stent proximally along the main branch and into the mother stent, as opposed to the prior configuration where the daughter stent is drawn along the side branch into the mother stent. The catheter system is advanced so the daughter balloon catheter leads the system and passes the ostium of the daughter vessel, while remaining in the mother vessel. As the catheter system is advanced further, the mother balloon catheter will enter the daughter vessel. The catheter system can only be advanced a certain distance toward the bifurcation, until it is stopped by the carina. It cannot be advanced beyond the bifurcation site because the tension of the daughter catheter on the mother stent will prevent the mother catheter from moving distally. At this time the distal portion of the mother stent is beyond the ostium of the daughter vessel and cannot be advanced any further. While the mother catheter is held in place, the daughter catheter is drawn back such that the proximal portion of the daughter balloon is partially in the mother stent. Alignment can be performed with radiopaque markers, in that the proximal markers on the two balloons are next to each other. The operator can then gently push the catheter system distally to maximize apposition to the carina. A stent on the daughter balloon (which is now partially under the mother stent) is aligned so that when the daughter balloon is inflated the daughter stent and the proximal portion of the mother stent expand simultaneously and give complete coverage of the mother vessel. The daughter vessel balloon is then deflated. The mother vessel balloon is then inflated and the distal portion of the mother stent is expanded. A kissing procedure can also be performed if required.

The mother vessel can be stented if necessary with any commercially available stent. A balloon on a wire could be used as an alternative to the daughter catheter. In an alternative embodiment, the catheter system can be arranged with the daughter balloon portion proximal to the mother balloon portion and advanced over the guidewires to the bifurcation. In the case of the mother catheter on the mother guidewire, the alignment of the mother stent with the ostium of the daughter vessel occurs because tension between the daughter guidewire and mother stent on the mother catheter prevents further advancement of the mother catheter. In the alternative case of the mother catheter on the daughter guidewire, the alignment of the mother stent with the ostium of the mother vessel occurs because tension between the mother guidewire and mother stent on the mother catheter (on the daughter guidewire) prevents further advancement of the mother catheter. In both cases the daughter stent is advanced into alignment with the mother stent and expanded. In preferred embodiments, the mother catheter is an over-the-wire (OTW) design and the daughter catheter is a rapid-exchange (RX) design with daughter catheter portion preferably distal thereto. The daughter balloon is placed just distal to the tip of the mother catheter, this arrangement minimizes the overall profile of the catheter system and allows maximal tracking of the arteries. The system may additionally have stents crimped over the balloons. The daughter stent may be any length, but in preferred embodiments is approximately half the length of the daughter balloon or mother stent. The proximal end of the mother stent may be crimped only slightly to allow the daughter catheter balloon portion to operate independently so that it may be pushed or pulled without dislodging the mother stent.

An exemplary method comprises the following steps:

1. Advance the catheter system to bifurcation, daughter balloon catheter portion and mother balloon catheter portion in their respective vessels.
2. The mother catheter is no longer able to advance because of the tension between the mother stent and daughter catheter.
3. The daughter balloon proximal portion is drawn back into the mother stent and aligned with radiopaque markers.
4. While holding both the mother and daughter catheters tightly, the operator pushes forward lightly.

5. Inflate the daughter balloon and expand the daughter stent, approximately half of the daughter balloon distal portion will expand the "half-stent," and half of the daughter balloon proximal portion will expand inside the mother vessel and partially expand the proximal portion of the mother stent. Expansion of the proximal portion of the mother stent and the daughter stent preferably occur simultaneously.
6. Once the daughter stent is fully deployed, then the mother balloon can be fully expanded to deploy the distal portion of the mother stent.
7. A conventional kissing procedure may be utilized to ensure full apposition. In one particular aspect, the daughter balloon catheter portion may be used without a stent. This allows perfect alignment of the mother stent around the ostium of the daughter vessel. The daughter balloon would be used for the alignment as outlined in step three above, and expands the proximal portion of the mother stent.

In an alternative embodiment, the mother catheter is an over-the-wire (OTW) design and the daughter catheter is a rapid-exchange (RX) design with daughter catheter portion distal thereto. The system may additionally have stents crimped over the balloons. The daughter stent is preferably less than the length of the mother balloon or stent, although this is not intended to be limiting, and the daughter stent may be any length The proximal end of the mother stent may be partially crimped to allow the daughter catheter balloon portion to operate independently, so that it may be pushed or pulled without restriction and minimum friction, and without dislodging or affecting the mother stent. An exemplary method comprises the following steps:

1. Looping the OTW so that one operator can hold both guide wires with one hand and then push both catheters with the other.
2. Advance the catheter system to bifurcation, daughter balloon catheter portion and mother balloon catheter portion aligned in their respective vessels, as disclosed in steps two through three in the above embodiment.
3. While holding both the mother and daughter catheters tightly, push the catheter system forward until the mother balloon catheter portion is stopped at the carina.
4. Inflate the daughter balloon and expand the daughter stent, approximately half of the daughter balloon distal portion will expand the "half-stent," and half of the daughter balloon proximal portion will expand inside the mother vessel and partially expand the proximal portion of the mother stent.
5. Once the daughter stent is fully deployed, then the mother balloon can be fully expanded to deploy the distal portion of the mother stent.
6. A conventional kissing procedure may be utilized to ensure full apposition.

In one particular aspect, the daughter balloon catheter portion may be used without a stent. This would allow perfect alignment of the mother stent around the ostium of the daughter vessel. The daughter balloon would be used for the alignment as outlined in step three above, and expand the proximal portion of the mother stent.

In an alternative embodiment, the mother catheter is an over-the-wire design and the daughter catheter is a rapid-exchange design with daughter catheter portion distal thereto. The system may additionally have stents crimped over the balloons. The daughter stent may be approximately half the length of the mother balloon or stent, but this is not intended to be limiting, and the daughter stent may be any length. The proximal end of the mother stent may be partially crimped to allow the daughter catheter balloon portion to operate independently, so that it may be pushed or pulled without dislodging the mother stent. An exemplary method comprises the following steps:

1. Place the daughter catheter over the guidewire in the daughter vessel and slide the system into the guide catheter without placing the mother balloon over a guidewire at this time. After the leading daughter catheter enters the coronary artery and just before the mother catheter exits the guide catheter, insert the mother guidewire through the mother catheter and into the mother vessel, then push the system out of the guide catheter over the two guidewires. This method mitigates wire wrap.
2. Advance the catheter system to the bifurcation, daughter balloon catheter portion and mother balloon catheter portion aligned in their respective vessels.
3. Advance the catheter system to bifurcation, daughter balloon catheter portion and mother balloon catheter portion aligned in their respective vessels, as disclosed in step two in the above embodiment. Pull the daughter catheter back until the proximal markers on both balloons are aligned.
4. Inflate the daughter balloon and expand the daughter stent, approximately half of the daughter balloon distal portion will expand the "half-stent," and half of the daughter balloon proximal portion will expand inside the mother vessel and partially expand the proximal portion of the mother stent.
5. Once the daughter stent is fully deployed, then the mother balloon can be fully expanded to deploy the distal portion of the mother stent.
6. A conventional kissing procedure may be utilized to ensure full apposition. In one particular aspect, the daughter balloon catheter portion may be used without a stent. This would allow perfect alignment of mother stent around the ostium of the daughter vessel. The daughter balloon would be used for the alignment as outlined in step three above, and expand the proximal portion of the mother stent.

In an alternative embodiment the mother and daughter systems balloons are aligned. This embodiment could include the mother stent and daughter stent or either stent. When there is both a mother stent and a daughter stent, the daughter stent is preferably shorter than the mother stent, although it may be any length, and in preferred embodiments is approximately half the length of the mother stent so that the daughter stent could be mounted on the distal half of the daughter balloon. Furthermore, the proximal portion of the daughter catheter shaft is positioned under the non-uniformly crimped mother stent. The dual stent arrangement reduces the profile compared to a full length stent that covers the entire length of the daughter balloon.

The methods described herein could alternatively include the step of flushing the catheters and the guidewire port to assist with maneuverability. The methods described herein could alternatively include the step of a couple of snap-on couplers that lock the two catheters together. In another particular aspect, each balloon catheter portion may include at least one radiopaque marker. With such a configuration, separation of the markers may be conveniently observed using fluoroscopy to indicate that the balloon catheter portions have passed beyond the ostium and the daughter balloon catheter portion has passed into the daughter vessel, thus aligning the passage of the stent with the ostium of the daughter vessel. In another particular aspect, the catheter systems design is contemplated to cover combinations of

rapid exchange and over the wire; for visualization purposes the hybrid versions are preferred because they are easier to distinguish while using fluoroscopy.

In another particular aspect, the proximal balloon may be differentially expandable, such that one end of the balloon may expand prior to the other end. In another particular aspect, the proximal balloon catheter portion may receive a stent that can be crimped under variable pressure to allow the distal balloon catheter portion freedom of movement.

In another particular aspect, a stent may be crimped over the proximal balloon catheter portion and the stent may be designed to deploy with variable profile to better oppose the patient anatomy.

In another particular aspect, the distal balloon catheter portion may be delivered via a pull away or peel away capture tube. All of the above embodiments may utilize mother vessel stents having any diameter, with diameter preferably ranging from about 2.5 to about 5 millimeters, and daughter vessel stent having any diameter, preferably ranging from about 2 to about 5 millimeters. The length of the stents may be any length, preferably in the range of about 4 to about 40 millimeters. The position of a stent on a catheter need not be fixed and may be positioned on either or both catheters.

Catheter Configurations:

FIG. **1**A illustrates an exemplary embodiment of the catheter system **100** with a distal daughter balloon catheter portion comprising a balloon with a daughter stent crimped thereon. The daughter stent may be shorter than the mother stent, and it may not be centered on its corresponding balloon in this as well as any other embodiments disclosed herein. Thus, in preferred embodiments, a proximal portion of the daughter balloon remains uncovered by a stent, as will be discussed in greater detail below. In a particular embodiment the daughter stent is preferably about half the length of the mother stent. The distal daughter stent is crimped under standard conditions known in the art. The proximal mother balloon catheter portion comprises a mother balloon and a mother stent. The mother stent is crimped differentially along the longitudinal direction and circumferentially. In this exemplary embodiment, the distal half of the mother stent is crimped under typical conditions to ensure that the mother stent is not dislodged during the alignment with the distal daughter balloon. Further, the proximal portion of the mother stent is crimped under non-standard, relatively loose conditions to allow the distal daughter balloon catheter portion freedom of movement even though a portion of the daughter balloon catheter portion is circumferentially enclosed. The mother and daughter catheters are slidably attached to each other via a hollow exchange port. The exchange port is embedded in the side of the mother over the wire catheter and has an inner diameter just large enough to allow the insertion of the rapid exchange daughter catheter and balloon. The exchange port may be any length that extends between a proximal portion of the balloons and a distal portion of the catheter connectors, and in this embodiment is about 10 centimeters long, but in preferred embodiments varies from about 1 centimeter to about 30 centimeters, and in more preferred embodiments is about 5 cm to about 10 cm long. The entry for the daughter catheter on the exchange port is proximal and the exit for the daughter catheter is on the distal end of the exchange port. The daughter catheter is loaded through the exchange port and the daughter balloon extends distally from the exit of the exchange port, preferably about 5 centimeters. However, it is possible to have the exchange port any distance from the mother balloon, but preferably about 1 to about 30 centimeters proximal to the mother balloon. The daughter stent can be crimped on to the balloon after it has been loaded through the exchange port. The exchange port preferably has a tight fit to reduce catheter profile and preferably has low friction to allow the operator to easily slide the catheters relative to each other.

FIG. **1**B more clearly illustrates the features of the catheter system **100** in FIG. **1**A. The stent delivery system **100** includes a first catheter **102**, and a second catheter **130**. The first catheter **102** includes an elongate shaft **104** with a radially expandable balloon **106** disposed near a distal end of the elongate shaft **104**. A stent **108** having a proximal portion **122**, a distal portion **114** and a side hole **120** is disposed over the balloon **106**. The distal portion **114** is crimped to the balloon **106** to prevent ejection during delivery, while the proximal portion **122** is partially crimped to the balloon **106** so the second catheter **130** may be slidably advanced or retracted under the proximal portion **122** of stent **108**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **112** extending from the distal guidewire port **110** at the distal end of the elongate shaft **104** to the proximal end of the elongate shaft **104** into Y-adapter **114** having a connector **116**. The connector **116** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **112** exits via connector **116**. A second connector **118**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **106** via an inflation lumen (not shown) in the elongate shaft **104**. The first catheter **102** also includes a hollow exchange port tube **124** coupled to the elongate shaft **104**. The hollow exchange port tube **124** may be coextruded with the first shaft **104**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The hollow exchange port may alternatively be coupled with the other shaft **132**. The hollow exchange port tube **124** includes a central channel **126** extending therethrough and is sized to slidably receive a portion of the second catheter **130**. Radiopaque markers may be placed at different locations along the shaft **104**, often near the balloon **106** and/or stent **108**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **130** includes an elongate shaft **132** with a radially expandable balloon **140** disposed near a distal end of the elongate shaft **132**. A stent **142** is disposed over balloon **140**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **142** is shorter than the working length of the balloon **140** so that a proximal portion of the balloon **140** is unconstrained by the stent **142** and this unconstrained portion of the balloon **140** may be slidably advanced or refracted through side hole **120** and under proximal portion **122** of stent **108** as will be discussed below. Stent **142** is crimped to balloon **140** to prevent ejection during delivery. At least a portion of balloon **140**, and stent **142** are distally offset relative to balloon **106** and stent **108** so as to minimize profile of the device. In this embodiment the distal stent **142** may be deployed in a main branch of the vessel and the other stent **108** may be deployed in a side branch of the vessel. Alternatively, the distal stent **142** may be deployed in a side branch of a vessel and the other stent **108** may be deployed in the main branch of a vessel. The second catheter **130** is a rapid exchange catheter

(RX) having a guidewire lumen **134** extending from the distal guidewire port **138** at the distal end of the elongate shaft **132** to a proximal guidewire port **136** which is closer to the distal port **138** than the proximal end of the catheter shaft **132**. The proximal guidewire port **136** is also unobstructed by the hollow exchange tube **124** and preferably proximal thereto. A connector **144**, preferably a Luer connector is connected to the proximal end of the elongate shaft **132** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **132** for inflation of balloon **140**. A portion of shaft **132** is disposed in the central channel **126** of the hollow exchange tube **124** and this helps keep the two catheter shafts **104**, **132** parallel and prevents tangling during delivery and as shaft **132** is slidably advanced or retracted relative to shaft **104**. Also, another portion of shaft **132** is disposed under proximal portion **122** of stent **108**. The second catheter **130** may also be slidably advanced or retracted under the proximal portion **122** of stent **108** so that the shaft **132** passes through the side hole **120** in stent **108**. Radiopaque markers may be placed at different locations on the shaft **132**, often near the balloon **140** or stent **142**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **2**A illustrates a cross sectional view of one embodiment of a catheter system **200** with the daughter catheter balloon portion distal to the mother balloon portion utilizing the same exchange port as described in FIG. **1**A. The mother balloon is preferably at least about 5 centimeters distal from the exit of the exchange port. As disclosed above the mother balloon could be distal from the exchange port from about 1 cm to about 30 centimeters.

FIG. **2**B more clearly illustrates the features of the catheter system **200** in FIG. **2**A. The stent delivery system **200** includes a first catheter **202**, and a second catheter **230**. The first catheter **202** includes an elongate shaft **204** with a radially expandable balloon **206** disposed near a distal end of the elongate shaft **204**, and a stent **208** disposed over the balloon **206**. The stent **208** may be the same length as the working length of the balloon **208**, or it may be shorter. In preferred embodiments, the stent **208** is shorter than the working length of balloon **206** such that a proximal portion of balloon **206** remains unconstrained by stent **208**. The proximal portion of balloon **206** may be slidably advanced and retracted under stent **242** via side hole **220**. Stent **208** is crimped to the balloon **206** to prevent ejection during delivery. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **212** extending from the distal guidewire port **210** at the distal end of the elongate shaft **204** to the proximal end of the elongate shaft **204** into Y-adapter **214** having a connector **216**. The connector **216** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **212** exits via connector **216**. A second connector **218**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **206** via an inflation lumen (not shown) in the elongate shaft **204**. The first catheter **202** also includes a hollow exchange port tube **224** coupled to the elongate shaft **204**. The hollow exchange port tube **224** may be coextruded with the first shaft **204**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The hollow exchange port may alternatively be coupled with the other shaft **232**. The hollow exchange port tube **224** includes a central channel **226** extending therethrough and is sized to slidably receive a portion of the second catheter **230**. Radiopaque markers may be placed at different locations along the shaft **204**, often near the balloon **206** and/or stent **208**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **230** includes an elongate shaft **232** with a radially expandable balloon **240** disposed near a distal end of the elongate shaft **232**. A stent **242** having a proximal portion **222**, a distal portion **214**, and a side hole **220** is disposed over balloon **240**. The distal portion **214** is crimped to balloon **240** to prevent ejection during delivery, while the proximal portion **222** is partially crimped to balloon **240** so elongate shaft **204** may be slidably advanced or retracted under the proximal portion **222** of stent **242**. The stent may preferably have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. At least a portion of balloon **206**, and stent **208** are distally offset relative to balloon **240** and stent **242** so as to minimize profile of the device. In this embodiment the distal stent **208** may be deployed in a main branch of the vessel and the other stent **242** may be deployed in a side branch of the vessel. Alternatively, the distal stent **208** may be deployed in a side branch of a vessel and the other stent **242** may be deployed in the main branch of a vessel. The second catheter **230** is a rapid exchange catheter (RX) having a guidewire lumen **234** extending from the distal guidewire port **238** at the distal end of the elongate shaft **232** to a proximal guidewire port **236** which is closer to the distal port **238** than the proximal end of the catheter shaft **232**. The proximal guidewire port **236** is also unobstructed by the hollow exchange tube **224** and preferably proximal thereto. A connector **244**, preferably a Luer connector is connected to the proximal end of the elongate shaft **232** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **232** for inflation of balloon **240**. A portion of shaft **232** is disposed in the central channel **226** of the hollow exchange tube **224** and this helps keep the two catheter shafts **204**, **232** parallel and prevents tangling during delivery and as shaft **232** is slidably advanced or retracted relative to shaft **204**. Also, a portion of shaft **204** is disposed under proximal portion **222** of stent **242**. The first catheter **202** may be slidably advanced or retracted under the proximal portion **222** of stent **242** so that the shaft **204** passes through the side hole **220** in stent **242**. Radiopaque markers may be placed at different locations on the shaft **232**, often near the balloon **240** or stent **242**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **3**A illustrates a cross sectional view of one embodiment of a catheter system **300** with the mother and daughter catheters both having a rapid exchange design. In this particular embodiment one of the catheters has a hollow exchange port embedded in its side and the other catheter is loaded through the exchange port. Typically, the catheter is loaded prior to having a stent crimped over the balloon portion.

FIG. **3**B more clearly illustrates the features of the catheter system **300** in FIG. **3**A. The stent delivery system **300** includes a first catheter **302**, and a second catheter **330**. The first catheter **302** includes an elongate shaft **304** with a radially expandable balloon **306** disposed near a distal end of the elongate shaft **304**. A stent **308** having a proximal portion **322**, a distal portion **314** and a side hole **320** is

disposed over the balloon **306**. The distal portion **314** is crimped to the balloon **306** to prevent ejection during delivery, while the proximal portion **322** is partially crimped to the balloon **306** so the second catheter **330** may be slidably advanced under the proximal portion **322** of stent **308**. The first catheter is a rapid exchange catheter (RX) having a guidewire lumen **312** extending from the distal guidewire port **310** at the distal end of the elongate shaft **304** to a proximal guidewire port **311** which is closer to the distal port **310** than the proximal end of the catheter shaft **304**. A connector **316** is coupled with the proximal end of the elongate shaft **304**. The connector **316** is preferably a Luer connector and this allows easy coupling with an Indeflator or other device for inflation of the balloon **306**. The first catheter **302** also includes a hollow exchange port tube **324** coupled to the elongate shaft **304**. The hollow exchange port tube **324** may be coextruded with the first shaft **304**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The hollow exchange port may alternatively be coupled with the other shaft **332**. The hollow exchange port tube **324** includes a central channel **326** extending therethrough and is sized to slidably receive a portion of the second catheter **330**. Radiopaque markers may be placed at different locations along the shaft **304**, often near the balloon **306** and/or stent **308**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **330** includes an elongate shaft **332** with a radially expandable balloon **340** disposed near a distal end of the elongate shaft **332**. A stent **342** is disposed over balloon **340**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **342** is shorter than the working length of the balloon **340** so that a proximal portion of the balloon **340** is unconstrained by the stent **342** and this unconstrained portion of the balloon **340** may be slidably advanced or refracted through side hole **320** and under proximal portion **322** of stent **308** as will be discussed below. Stent **342** is crimped to balloon **340** to prevent ejection during delivery. At least a portion of balloon **340**, and stent **342** are distally offset relative to balloon **306** and stent **308** so as to minimize profile of the device. In this embodiment the distal stent **342** may be deployed in a main branch of the vessel and the other stent **308** may be deployed in a side branch of the vessel. Alternatively, the distal stent **342** may be deployed in a side branch of a vessel and the other stent **308** may be deployed in the main branch of a vessel. The second catheter **330** is a rapid exchange catheter (RX) having a guidewire lumen **334** extending from the distal guidewire port **338** at the distal end of the elongate shaft **332** to a proximal guidewire port **336** which is closer to the distal port **338** than the proximal end of the catheter shaft **332**. The proximal guidewire port **336** is also unobstructed by the hollow exchange tube **324** and may be distal thereto. A connector **344**, preferably a Luer connector is connected to the proximal end of the elongate shaft **332** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **332** for inflation of balloon **340**. A portion of shaft **332** is disposed in the central channel **326** of the hollow exchange tube **324** and this helps keep the two catheter shafts **304**, **332** parallel and prevents tangling during delivery and as shaft **332** is slidably advanced or retracted relative to shaft **304**. Also, another portion of shaft **332** is disposed under proximal portion **322** of stent **308**. The second catheter **330** may also be slidably advanced or retracted under the proximal portion **322** of stent **308** so that the shaft **332** passes through the side hole **320** in stent **308**. Radiopaque markers may be placed at different locations on the shaft **332**, often near the balloon **340** or stent **342**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **4**A illustrates a cross sectional view of one embodiment of a catheter system **400** with the mother and daughter catheters both having an over the wire design. In this particular embodiment one of the catheters has a hollow exchange port embedded in its side and the other catheter does not have a hollow exchange port. The catheter without the exchange port is loaded onto the catheter with an exchange port. Typically, the catheter would have to be loaded prior to having a stent crimped over the balloon portion.

FIG. **4**B more clearly illustrates the features of the catheter system **400** in FIG. **4**A. The stent delivery system **400** includes a first catheter **402**, and a second catheter **430**. The first catheter **402** includes an elongate shaft **404** with a radially expandable balloon **406** disposed near a distal end of the elongate shaft **404**. A stent **408** having a proximal portion **422**, a distal portion **414** and a side hole **420** is disposed over the balloon **406**. The distal portion **414** is crimped to the balloon **406** to prevent ejection during delivery, while the proximal portion **422** is partially crimped to the balloon **406** so the second catheter **430** may be slidably advanced under the proximal portion **422** of stent **408**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **412** extending from the distal guidewire port **410** at the distal end of the elongate shaft **404** to the proximal end of the elongate shaft **404** into Y-adapter **414** having a connector **416**. The connector **416** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **412** exits via connector **416**. A second connector **418**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **406** via an inflation lumen (not shown) in the elongate shaft **404**. The first catheter **402** also includes a hollow exchange port tube **424** coupled to the elongate shaft **404**. The hollow exchange port tube **424** may be coextruded with the first shaft **404**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The hollow exchange port may alternatively be coupled with the other shaft **432**. The hollow exchange port tube **424** includes a central channel **426** extending therethrough and is sized to slidably receive a portion of the second catheter **430**. Radiopaque markers may be placed at different locations along the shaft **404**, often near the balloon **406** and/or stent **408**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **430** includes an elongate shaft **432** with a radially expandable balloon **440** disposed near a distal end of the elongate shaft **432**. A stent **442** is disposed over balloon **440**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **442** is shorter than the working length of the balloon **440** so that a proximal portion of the balloon **440** is unconstrained by the stent **442** and this

unconstrained portion of the balloon **440** may be slidably advanced or refracted through side hole **420** and under proximal portion **422** of stent **408** as will be discussed below. Stent **442** is crimped to balloon **440** to prevent ejection during delivery. At least a portion of balloon **440**, and stent **442** are distally offset relative to balloon **406** and stent **408** so as to minimize profile of the device. In this embodiment the distal stent **442** may be deployed in a main branch of the vessel and the other stent **408** may be deployed in a side branch of the vessel. Alternatively, the distal stent **442** may be deployed in a side branch of a vessel and the other stent **408** may be deployed in the main branch of a vessel. The second catheter **430** is an over-the-wire (OTW) catheter having a guidewire lumen **434** extending from the distal guidewire port **438** at the distal end of the elongate shaft **432** to the proximal end of the elongate shaft **432** into Y-adapter **446** having a connector **448**. The connector **448** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **434** exits via connector **448**. A second connector **444**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **440** via an inflation lumen (not shown) in the elongate shaft **432**. A portion of shaft **432** is disposed in the central channel **426** of the hollow exchange tube **424** and this helps keep the two catheter shafts **404**, **432** parallel and prevents tangling during delivery and as shaft **432** is slidably advanced or retracted relative to shaft **404**. Also, another portion of shaft **432** is disposed under proximal portion **422** of stent **408**. The second catheter **430** may also be slidably advanced or retracted under the proximal portion **422** of stent **408** so that the shaft **432** passes through the side hole **420** in stent **408**. Radiopaque markers may be placed at different locations on the shaft **432**, often near the balloon **440** or stent **442**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIGS. **5**A, **6**A, **7**A, and **8**A illustrate an end to end capture tube that connects the catheters together. The capture tube keeps the catheters from tangling. The capture tube preferably remains in place during the entire clinical procedure. In these exemplary embodiments, the capture tube is a thin polymer hollow straw that covers the mother and daughter catheters from a point about 10 centimeters distal to the Indeflator attachment to a distal point that is about 10 centimeters proximal from the rapid exchange catheter's proximal rapid exchange port.

FIG. **5**A illustrates a catheter system **500** having a distal daughter catheter with a rapid exchange configuration and a proximal mother catheter with an over-the-wire configuration. FIG. **5**B more clearly illustrates the features of the catheter system **500** seen in FIG. **5**A. The stent delivery system **500** includes a first catheter **502**, and a second catheter **530**. The first catheter **502** includes an elongate shaft **504** with a radially expandable balloon **506** disposed near a distal end of the elongate shaft **504**. A stent **508** having a proximal portion **522**, a distal portion **514** and a side hole **520** is disposed over the balloon **506**. The distal portion **514** is crimped to the balloon **506** to prevent ejection during delivery, while the proximal portion **522** is partially crimped to the balloon **506** so the second catheter **530** may be slidably advanced under the proximal portion **522** of stent **508**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **512** extending from the distal guidewire port **510** at the distal end of the elongate shaft **504** to the proximal end of the elongate shaft **504** into Y-adapter **514** having a connector **516**. The connector **516** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **512** exits via connector **516**. A second connector **518**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **506** via an inflation lumen (not shown) in the elongate shaft **504**. The first catheter **502** is disposed in the central channel **526** of a capture tube **524**. Central channel **526** is sized to fit both shafts **504**, **532** and allow slidable movement thereof. Shaft **504** is slidable in the central channel **526**, or it may be locked with a locking collar **525** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **504**, often near the balloon **506** and/or stent **508**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **530** includes an elongate shaft **532** with a radially expandable balloon **540** disposed near a distal end of the elongate shaft **532**. A stent **542** is disposed over balloon **540**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **542** is shorter than the working length of the balloon **540** so that a proximal portion of the balloon **540** is unconstrained by the stent **542** and this unconstrained portion of the balloon **540** may be slidably advanced or refracted through side hole **520** and under proximal portion **522** of stent **508** as will be discussed below. Stent **542** is crimped to balloon **540** to prevent ejection during delivery. At least a portion of balloon **540**, and stent **542** are distally offset relative to balloon **506** and stent **508** so as to minimize profile of the device. In this embodiment the distal stent **542** may be deployed in a main branch of the vessel and the other stent **508** may be deployed in a side branch of the vessel. Alternatively, the distal stent **542** may be deployed in a side branch of a vessel and the other stent **508** may be deployed in the main branch of a vessel. The second catheter **530** is a rapid exchange catheter (RX) having a guidewire lumen **534** extending from the distal guidewire port **538** at the distal end of the elongate shaft **532** to a proximal guidewire port **536** which is closer to the distal port **538** than the proximal end of the catheter shaft **532**. The proximal guidewire port **536** is also unobstructed by the capture tube **524** and may be distal thereto. A connector **544**, preferably a Luer connector is connected to the proximal end of the elongate shaft **532** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **532** for inflation of balloon **540**. A portion of shaft **532** is disposed in the central channel **526** of the capture tube **524** and this helps keep the two catheter shafts **504**, **532** parallel and prevents tangling during delivery and as shaft **532** is slidably advanced in the central channel **526**. Compression fitting **525** may be used to lock elongate shafts **504**, **532** in the capture tube **524** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, another portion of shaft **532** is disposed under proximal portion **522** of stent **508**. The second catheter **530** may also be slidably advanced or retracted under the proximal portion **522** of stent **508** so that the shaft **532** passes through the side hole **520** in stent **508**. Radiopaque markers may be placed at different locations on the shaft **532**, often near the balloon **540** or stent **542**, to help mark the proximal and distal ends of the stent or balloon, as

well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **6**A illustrates a catheter system **600** having a distal daughter catheter with an over the wire design and a proximal mother catheter with a rapid exchange design. FIG. **6**B more clearly illustrates the features of the catheter system **600** in FIG. **6**A. The stent delivery system **600** includes a first catheter **602**, and a second catheter **630**. The first catheter **602** includes an elongate shaft **604** with a radially expandable balloon **606** disposed near a distal end of the elongate shaft **604**, and a stent **608** disposed over the balloon **606**. The stent **608** may be the same length as the working length of the balloon **608**, or it may be shorter. In preferred embodiments, the stent **608** is shorter than the working length of balloon **606** such that a proximal portion of balloon **606** remains unconstrained by stent **608**. The proximal portion of balloon **606** may be slidably advanced and retracted under stent **642** via side hole **620**. Stent **608** is crimped to the balloon **606** to prevent ejection during delivery. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **612** extending from the distal guidewire port **610** at the distal end of the elongate shaft **604** to the proximal end of the elongate shaft **604** into Y-adapter **614** having a connector **616**. The connector **616** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **612** exits via connector **616**. A second connector **618**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **606** via an inflation lumen (not shown) in the elongate shaft **604**. The first catheter **602** is disposed in the central channel **626** of a capture tube **624**. Central channel **626** is sized to fit both shafts **604**, **632** and allow slidable movement thereof. Shaft **604** is slidable in the central channel **626**, or it may be locked with a locking collar **625** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **604**, often near the balloon **606** and/or stent **608**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **630** includes an elongate shaft **632** with a radially expandable balloon **640** disposed near a distal end of the elongate shaft **632**. A stent **642** having a proximal portion **622**, a distal portion **614**, and a side hole **620** is disposed over balloon **640**. The distal portion **614** is crimped to balloon **640** to prevent ejection during delivery, while the proximal portion **622** is partially crimped to balloon **640** so elongate shaft **604** may be slidably advanced or retracted under the proximal portion **622** of stent **642**. The stent may preferably have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. At least a portion of balloon **606**, and stent **608** are distally offset relative to balloon **640** and stent **642** so as to minimize profile of the device. In this embodiment the distal stent **608** may be deployed in a main branch of the vessel and the other stent **642** may be deployed in a side branch of the vessel. Alternatively, the distal stent **608** may be deployed in a side branch of a vessel and the other stent **642** may be deployed in the main branch of a vessel. The second catheter **630** is a rapid exchange catheter (RX) having a guidewire lumen **634** extending from the distal guidewire port **638** at the distal end of the elongate shaft **632** to a proximal guidewire port **636** which is closer to the distal port **638** than the proximal end of the catheter shaft **632**. The proximal guidewire port **636** is also unobstructed by the capture tube **624** and may be distal thereto. A connector **644**, preferably a Luer connector is connected to the proximal end of the elongate shaft **632** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **632** for inflation of balloon **640**. A portion of shaft **632** is disposed in the central channel **626** of the capture tube **624** and this helps keep the two catheter shafts **604**, **632** parallel and prevents tangling during delivery and as shaft **604** is slidably advanced in the central channel **626**. Compression fitting **625** may be used to lock elongate shafts **604**, **632** in the capture tube **624** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, a portion of shaft **604** is disposed under proximal portion **622** of stent **642**. The first catheter **602** may be slidably advanced or retracted under the proximal portion **622** of stent **642** so that the shaft **604** passes through the side hole **620** in stent **642**. Radiopaque markers may be placed at different locations on the shaft **632**, often near the balloon **640** or stent **642**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **7**A shows a catheter system **700** having dual rapid exchange mother and daughter catheters so the end point of the capture tube is preferably about 10 centimeters proximal from the rapid exchange port on the distal most catheter. FIG. **7**B more clearly illustrates the features of the catheter system **700** in FIG. **7**A. The stent delivery system **700** includes a first catheter **702**, and a second catheter **730**. The first catheter **702** includes an elongate shaft **704** with a radially expandable balloon **706** disposed near a distal end of the elongate shaft **704**. A stent **708** having a proximal portion **722**, a distal portion **714** and a side hole **720** is disposed over the balloon **706**. The distal portion **714** is crimped to the balloon **706** to prevent ejection during delivery, while the proximal portion **722** is partially crimped to the balloon **706** so the second catheter **730** may be slidably advanced under the proximal portion **722** of stent **708**. The first catheter is a rapid exchange catheter (RX) having a guidewire lumen **712** extending from the distal guidewire port **710** at the distal end of the elongate shaft **704** to a proximal guidewire port **711** which is closer to the distal port **710** than the proximal end of the catheter shaft **704**. A connector **716** is coupled with the proximal end of the elongate shaft **704**. The connector **716** is preferably a Luer connector and this allows easy coupling with an Indeflator or other device for inflation of the balloon **706**. The first catheter **702** is disposed in the central channel **726** of a capture tube **724**. Central channel **726** is sized to fit both shafts **704**, **732** and allow slidable movement thereof. Shaft **704** is slidable in the central channel **726**, or it may be locked with a locking collar **725** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **704**, often near the balloon **706** and/or stent **708**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **730** includes an elongate shaft **732** with a radially expandable balloon **740** disposed near a distal end of the elongate shaft **732**. A stent **742** is disposed over balloon **740**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **742** is shorter than the working length of the balloon **740** so that a proximal portion of the balloon **740** is unconstrained by the stent **742** and this

unconstrained portion of the balloon **740** may be slidably advanced or refracted through side hole **720** and under proximal portion **722** of stent **708** as will be discussed below. Stent **742** is crimped to balloon **740** to prevent ejection during delivery. At least a portion of balloon **740**, and stent **742** are distally offset relative to balloon **706** and stent **708** so as to minimize profile of the device. In this embodiment the distal stent **742** may be deployed in a main branch of the vessel and the other stent **708** may be deployed in a side branch of the vessel. Alternatively, the distal stent **742** may be deployed in a side branch of a vessel and the other stent **708** may be deployed in the main branch of a vessel. The second catheter **730** is a rapid exchange catheter (RX) having a guidewire lumen **734** extending from the distal guidewire port **738** at the distal end of the elongate shaft **732** to a proximal guidewire port **736** which is closer to the distal port **738** than the proximal end of the catheter shaft **732**. The proximal guidewire port **736** is also unobstructed by the capture tube **724** and may be distal thereto. A connector **744**, preferably a Luer connector is connected to the proximal end of the elongate shaft **732** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **732** for inflation of balloon **740**. A portion of shaft **732** is disposed in the central channel **726** of the capture tube **724** and this helps keep the two catheter shafts **704**, **732** parallel and prevents tangling during delivery and as shaft **732** is slidably advanced in the central channel **726**. Compression fitting **725** may be used to lock elongate shafts **704**, **732** in the capture tube **724** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, another portion of shaft **732** is disposed under proximal portion **722** of stent **708**. The second catheter **730** may also be slidably advanced or retracted under the proximal portion **722** of stent **708** so that the shaft **732** passes through the side hole **720** in stent **708**. Radiopaque markers may be placed at different locations on the shaft **732**, often near the balloon **740** or stent **742**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **8**A embodies a catheter system **800** with dual over the wire designs, therefore the capture tube ending point ends preferably about 30 centimeters proximal from the balloon portion of the most distal catheter. FIG. **8**B more clearly illustrates the features of the catheter system **800** in FIG. **8**A. The stent delivery system **800** includes a first catheter **802**, and a second catheter **830**. The first catheter **802** includes an elongate shaft **804** with a radially expandable balloon **806** disposed near a distal end of the elongate shaft **804**. A stent **808** having a proximal portion **822**, a distal portion **814** and a side hole **820** is disposed over the balloon **806**. The distal portion **814** is crimped to the balloon **806** to prevent ejection during delivery, while the proximal portion **822** is partially crimped to the balloon **806** so the second catheter **830** may be slidably advanced under the proximal portion **822** of stent **808**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **812** extending from the distal guidewire port **810** at the distal end of the elongate shaft **804** to the proximal end of the elongate shaft **804** into Y-adapter **814** having a connector **816**. The connector **816** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **812** exits via connector **816**. A second connector **818**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **806** via an inflation lumen (not shown) in the elongate shaft **804**. The first catheter **802** is disposed in the central channel **826** of a capture tube **824**. Central channel **826** is sized to fit both shafts **804**, **832** and allow slidable movement thereof. Shaft **804** is slidable in the central channel **826**, or it may be locked with a locking collar **825** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **804**, often near the balloon **806** and/or stent **808**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **830** includes an elongate shaft **832** with a radially expandable balloon **840** disposed near a distal end of the elongate shaft **832**. A stent **842** is disposed over balloon **840**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **842** is shorter than the working length of the balloon **840** so that a proximal portion of the balloon **840** is unconstrained by the stent **842** and this unconstrained portion of the balloon **840** may be slidably advanced or refracted through side hole **820** and under proximal portion **822** of stent **808** as will be discussed below. Stent **842** is crimped to balloon **840** to prevent ejection during delivery. At least a portion of balloon **840**, and stent **842** are distally offset relative to balloon **806** and stent **808** so as to minimize profile of the device. In this embodiment the distal stent **842** may be deployed in a main branch of the vessel and the other stent **808** may be deployed in a side branch of the vessel. Alternatively, the distal stent **842** may be deployed in a side branch of a vessel and the other stent **808** may be deployed in the main branch of a vessel. The second catheter **830** is an over-the-wire (OTW) catheter having a guidewire lumen **834** extending from the distal guidewire port **838** at the distal end of the elongate shaft **832** to the proximal end of the elongate shaft **832** into Y-adapter **846** having a connector **848**. The connector **848** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **834** exits via connector **848**. A second connector **844**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **840** via an inflation lumen (not shown) in the elongate shaft **832**. A portion of shaft **832** is disposed in the central channel **826** of the capture tube **824** and this helps keep the two catheter shafts **804**, **832** parallel and prevents tangling during delivery and as shaft **832** is slidably advanced in the central channel **826**. Compression fitting **825** may be used to lock elongate shafts **804**, **832** in the capture tube **824** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, another portion of shaft **832** is disposed under proximal portion **822** of stent **808**. The second catheter **830** may also be slidably advanced or retracted under the proximal portion **822** of stent **808** so that the shaft **832** passes through the side hole **820** in stent **808**. Radiopaque markers may be placed at different locations on the shaft **832**, often near the balloon **840** or stent **842**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIGS. **9**A, **10**A, **11**A, and **12**A illustrate a removable capture tube that is fitted over the dual catheters as described above but the capture tube has a polymer appendage. Once the operator has the catheter system placed near the bifur-

cation the operator can grab hold of the polymer appendage and pull the capture tube off of the catheters.

FIG. **9**A illustrates a catheter system **900** having a distal daughter catheter with a rapid exchange configuration and a proximal mother catheter with an over the wire configuration. FIG. **9**B more clearly illustrates the features of the catheter system **900** seen in FIG. **9**A. The stent delivery system **900** includes a first catheter **902**, and a second catheter **930**. The first catheter **902** includes an elongate shaft **904** with a radially expandable balloon **906** disposed near a distal end of the elongate shaft **904**. A stent **908** having a proximal portion **922**, a distal portion **914** and a side hole **920** is disposed over the balloon **906**. The distal portion **914** is crimped to the balloon **906** to prevent ejection during delivery, while the proximal portion **922** is partially crimped to the balloon **906** so the second catheter **930** may be slidably advanced under the proximal portion **922** of stent **908**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **912** extending from the distal guidewire port **910** at the distal end of the elongate shaft **904** to the proximal end of the elongate shaft **904** into Y-adapter **914** having a connector **916**. The connector **916** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **912** exits via connector **916**. A second connector **918**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **906** via an inflation lumen (not shown) in the elongate shaft **904**. The first catheter **902** is disposed in the central channel **926** of a capture tube **924** having a perforated region **945** along its longitudinal length. Central channel **926** is sized to fit both shafts **904**, **932** and allow slidable movement thereof. Shaft **904** is slidable in the central channel **926**, or it may be locked with a locking collar **925** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **904**, often near the balloon **906** and/or stent **908**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification. The perforated region **945** along the capture tube **924** allows the capture tube to be easily peeled away from both catheter shafts **904**, **932** once the catheters have been properly positioned and when no longer needed.

The second catheter **930** includes an elongate shaft **932** with a radially expandable balloon **940** disposed near a distal end of the elongate shaft **932**. A stent **942** is disposed over balloon **940**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **942** is shorter than the working length of the balloon **940** so that a proximal portion of the balloon **940** is unconstrained by the stent **942** and this unconstrained portion of the balloon **940** may be slidably advanced or refracted through side hole **920** and under proximal portion **922** of stent **908** as will be discussed below. Stent **942** is crimped to balloon **940** to prevent ejection during delivery. At least a portion of balloon **940**, and stent **942** are distally offset relative to balloon **906** and stent **908** so as to minimize profile of the device. In this embodiment the distal stent **942** may be deployed in a main branch of the vessel and the other stent **908** may be deployed in a side branch of the vessel. Alternatively, the distal stent **942** may be deployed in a side branch of a vessel and the other stent **908** may be deployed in the main branch of a vessel. The second catheter **930** is a rapid exchange catheter (RX) having a guidewire lumen **934** extending from the distal guidewire port **938** at the distal end of the elongate shaft **932** to a proximal guidewire port **936** which is closer to the distal port **938** than the proximal end of the catheter shaft **932**. The proximal guidewire port **936** is also unobstructed by the capture tube **924** and may be distal thereto. A connector **944**, preferably a Luer connector is connected to the proximal end of the elongate shaft **932** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **932** for inflation of balloon **940**. A portion of shaft **932** is disposed in the central channel **926** of the capture tube **924** and this helps keep the two catheter shafts **904**, **932** parallel and prevents tangling during delivery and as shaft **932** is slidably advanced in the central channel **926**. Compression fitting **925** may be used to lock elongate shafts **904**, **932** in the capture tube **924** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, another portion of shaft **932** is disposed under proximal portion **922** of stent **908**. The second catheter **930** may also be slidably advanced or retracted under the proximal portion **922** of stent **908** so that the shaft **932** passes through the side hole **920** in stent **908**. Capture tube **924** may be peeled away from shaft **932** by severing the perforated region **945**. Radiopaque markers may be placed at different locations on the shaft **932**, often near the balloon **940** or stent **942**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **10**A illustrates a catheter system **1000** having a distal daughter catheter with an over the wire design and a proximal mother catheter with a rapid exchange design. FIG. **10**B more clearly illustrates the features of the catheter system **1000** in FIG. **10**A. The stent delivery system **1000** includes a first catheter **1002**, and a second catheter **1030**. The first catheter **1002** includes an elongate shaft **1004** with a radially expandable balloon **1006** disposed near a distal end of the elongate shaft **1004**, and a stent **1008** disposed over the balloon **1006**. The stent **1008** may be the same length as the working length of the balloon **1008**, or it may be shorter. In preferred embodiments, the stent **1008** is shorter than the working length of balloon **1006** such that a proximal portion of balloon **1006** remains unconstrained by stent **1008**. The proximal portion of balloon **1006** may be slidably advanced and retracted under stent **1042** via side hole **1020**. Stent **1008** is crimped to the balloon **1006** to prevent ejection during delivery. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1012** extending from the distal guidewire port **1010** at the distal end of the elongate shaft **1004** to the proximal end of the elongate shaft **1004** into Y-adapter **1014** having a connector **1016**. The connector **1016** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1012** exits via connector **1016**. A second connector **1018**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1006** via an inflation lumen (not shown) in the elongate shaft **1004**. The first catheter **1002** is disposed in the central channel **1026** of a capture tube **1024** having perforated region **1045**. Central channel **1026** is sized to fit both shafts **1004**, **1032** and allow slidable movement thereof. Shaft **1004** is slidable in the central channel **1026**, or it may be locked with a locking collar **1025** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **1004**, often near the balloon **1006** and/or

stent **1008**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification. The perforated region **1045** along the capture tube **1024** allows the capture tube to be easily peeled away from both catheter shafts **1004**, **1032** once the catheters have been properly positioned and when no longer needed.

The second catheter **1030** includes an elongate shaft **1032** with a radially expandable balloon **1040** disposed near a distal end of the elongate shaft **1032**. A stent **1042** having a proximal portion **1022**, a distal portion **1014**, and a side hole **1020** is disposed over balloon **1040**. The distal portion **1014** is crimped to balloon **1040** to prevent ejection during delivery, while the proximal portion **1022** is partially crimped to balloon **1040** so elongate shaft **1004** may be slidably advanced or retracted under the proximal portion **1022** of stent **1042**. The stent may preferably have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. At least a portion of balloon **1006**, and stent **1008** are distally offset relative to balloon **1040** and stent **1042** so as to minimize profile of the device. In this embodiment the distal stent **1008** may be deployed in a main branch of the vessel and the other stent **1042** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1008** may be deployed in a side branch of a vessel and the other stent **1042** may be deployed in the main branch of a vessel. The second catheter **1030** is a rapid exchange catheter (RX) having a guidewire lumen **1034** extending from the distal guidewire port **1038** at the distal end of the elongate shaft **1032** to a proximal guidewire port **1036** which is closer to the distal port **1038** than the proximal end of the catheter shaft **1032**. The proximal guidewire port **1036** is also unobstructed by the capture tube **1024** and may be distal thereto. A connector **1044**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1032** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1032** for inflation of balloon **1040**. A portion of shaft **1032** is disposed in the central channel **1026** of the capture tube **1024** and this helps keep the two catheter shafts **1004**, **1032** parallel and prevents tangling during delivery and as shaft **1032** is slidably advanced in the central channel **1026**. Compression fitting **1025** may be used to lock elongate shafts **1004**, **1032** in the capture tube **1024** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, a portion of shaft **1004** is disposed under proximal portion **1022** of stent **1042**. The first catheter **1002** may be slidably advanced or retracted under the proximal portion **1022** of stent **1042** so that the shaft **1004** passes through the side hole **1020** in stent **1042**. Capture tube **1024** may be peeled away from shaft **1032** by severing the perforated region **1045**. Radiopaque markers may be placed at different locations on the shaft **1032**, often near the balloon **1040** or stent **1042**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **11**A illustrates a catheter system **1100** having dual rapid exchange design with a removable capture tube. FIG. **11**B more clearly illustrates the features of the catheter system **1100** in FIG. **11**A. The stent delivery system **1100** includes a first catheter **1102**, and a second catheter **1130**. The first catheter **1102** includes an elongate shaft **1104** with a radially expandable balloon **1106** disposed near a distal end of the elongate shaft **1104**. A stent **1108** having a proximal portion **1122**, a distal portion **1114** and a side hole **1120** is disposed over the balloon **1106**. The distal portion **1114** is crimped to the balloon **1106** to prevent ejection during delivery, while the proximal portion **1122** is partially crimped to the balloon **1106** so the second catheter **1130** may be slidably advanced under the proximal portion **1122** of stent **1108**. The first catheter is a rapid exchange catheter (RX) having a guidewire lumen **1112** extending from the distal guidewire port **1110** at the distal end of the elongate shaft **1104** to a proximal guidewire port **1111** which is closer to the distal port **1110** than the proximal end of the catheter shaft **1104**. A connector **1116** is coupled with the proximal end of the elongate shaft **1104**. The connector **1116** is preferably a Luer connector and this allows easy coupling with an Indeflator or other device for inflation of the balloon **1106**. The first catheter **1102** is disposed in the central channel **1126** of a capture tube **1124** having a perforated region **1145**. Central channel **1126** is sized to fit both shafts **1104**, **1132** and allow slidable movement thereof. Shaft **1104** is slidable in the central channel **1126**, or it may be locked with a locking collar **1125** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **1104**, often near the balloon **1106** and/or stent **1108**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification. The perforated region **1145** along the capture tube **1124** allows the capture tube to be easily peeled away from both catheter shafts **1104**, **1132** once the catheters have been properly positioned and when no longer needed.

The second catheter **1130** includes an elongate shaft **1132** with a radially expandable balloon **1140** disposed near a distal end of the elongate shaft **1132**. A stent **1142** is disposed over balloon **1140**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1142** is shorter than the working length of the balloon **1140** so that a proximal portion of the balloon **1140** is unconstrained by the stent **1142** and this unconstrained portion of the balloon **1140** may be slidably advanced or retracted through side hole **1120** and under proximal portion **1122** of stent **1108** as will be discussed below. Stent **1142** is crimped to balloon **1140** to prevent ejection during delivery. At least a portion of balloon **1140**, and stent **1142** are distally offset relative to balloon **1106** and stent **1108** so as to minimize profile of the device. In this embodiment the distal stent **1142** may be deployed in a main branch of the vessel and the other stent **1108** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1142** may be deployed in a side branch of a vessel and the other stent **1108** may be deployed in the main branch of a vessel. The second catheter **1130** is a rapid exchange catheter (RX) having a guidewire lumen **1134** extending from the distal guidewire port **1138** at the distal end of the elongate shaft **1132** to a proximal guidewire port **1136** which is closer to the distal port **1138** than the proximal end of the catheter shaft **1132**. The proximal guidewire port **1136** is also unobstructed by the capture tube **1124** and may be distal thereto. A connector **1144**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1132** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1132** for inflation of balloon **1140**. A portion of shaft **1132** is disposed in the central channel **1126** of the capture tube **1124** and this helps keep the two catheter shafts **1104**, **1132** parallel and prevents tangling during delivery and as shaft **1132** is slidably advanced in the central channel **1126**. Compression

fitting **1125** may be used to lock elongate shafts **1104**, **1132** in the capture tube **1124** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, another portion of shaft **1132** is disposed under proximal portion **1122** of stent **1108**. The second catheter **1130** may also be slidably advanced or retracted under the proximal portion **1122** of stent **1108** so that the shaft **1132** passes through the side hole **1120** in stent **1108**. Capture tube **1124** may be peeled away from shaft **1132** by severing the perforated region **1145**. Radiopaque markers may be placed at different locations on the shaft **1132**, often near the balloon **1140** or stent **1142**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **12**A illustrates a catheter system **1200** having dual over the wire design with a removable capture tube. FIG. **12**B more clearly illustrates the features of the catheter system **1200** in FIG. **12**A. The stent delivery system **1200** includes a first catheter **1202**, and a second catheter **1230**. The first catheter **1202** includes an elongate shaft **1204** with a radially expandable balloon **1206** disposed near a distal end of the elongate shaft **1204**. A stent **1208** having a proximal portion **1222**, a distal portion **1214** and a side hole **1220** is disposed over the balloon **1206**. The distal portion **1214** is crimped to the balloon **1206** to prevent ejection during delivery, while the proximal portion **1222** is partially crimped to the balloon **1206** so the second catheter **1230** may be slidably advanced under the proximal portion **1222** of stent **1208**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1212** extending from the distal guidewire port **1210** at the distal end of the elongate shaft **1204** to the proximal end of the elongate shaft **1204** into Y-adapter **1214** having a connector **1216**. The connector **1216** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1212** exits via connector **1216**. A second connector **1218**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1206** via an inflation lumen (not shown) in the elongate shaft **1204**. The first catheter **1202** is disposed in the central channel **1226** of a capture tube **1224** having a perforated region **1245**. Central channel **1226** is sized to fit both shafts **1204**, **1232** and allow slidable movement thereof. Shaft **1204** is slidable in the central channel **1226**, or it may be locked with a locking collar **1225** such as a Tuohy-Borst compression fitting. Radiopaque markers may be placed at different locations along the shaft **1204**, often near the balloon **1206** and/or stent **1208**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification. The perforated region **1245** along the capture tube **1224** allows the capture tube to be easily peeled away from both catheter shafts **1204**, **1232** once the catheters have been properly positioned and when no longer needed.

The second catheter **1230** includes an elongate shaft **1232** with a radially expandable balloon **1240** disposed near a distal end of the elongate shaft **1232**. A stent **1242** is disposed over balloon **1240**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1242** is shorter than the working length of the balloon **1240** so that a proximal portion of the balloon **1240** is unconstrained by the stent **1242** and this unconstrained portion of the balloon **1240** may be slidably advanced or retracted through side hole **1220** and under proximal portion **1222** of stent **1208** as will be discussed below. Stent **1242** is crimped to balloon **1240** to prevent ejection during delivery. At least a portion of balloon **1240**, and stent **1242** are distally offset relative to balloon **1206** and stent **1208** so as to minimize profile of the device. In this embodiment the distal stent **1242** may be deployed in a main branch of the vessel and the other stent **1208** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1242** may be deployed in a side branch of a vessel and the other stent **1208** may be deployed in the main branch of a vessel. The second catheter **1230** is an over-the-wire (OTW) catheter having a guidewire lumen **1234** extending from the distal guidewire port **1238** at the distal end of the elongate shaft **1232** to the proximal end of the elongate shaft **1232** into Y-adapter **1246** having a connector **1248**. The connector **1248** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1234** exits via connector **1248**. A second connector **1244**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1240** via an inflation lumen (not shown) in the elongate shaft **1232**. A portion of shaft **1232** is disposed in the central channel **1226** of the capture tube **1224** and this helps keep the two catheter shafts **1204**, **1232** parallel and prevents tangling during delivery and as shaft **1232** is slidably advanced in the central channel **1226**. Compression fitting **1225** may be used to lock elongate shafts **1204**, **1232** in the capture tube **1224** to prevent axial movement. The compression fitting may be a Tuohy-Borst fitting. Also, another portion of shaft **1232** is disposed under proximal portion **1222** of stent **1208**. The second catheter **1230** may also be slidably advanced or retracted under the proximal portion **1222** of stent **1208** so that the shaft **1232** passes through the side hole **1220** in stent **1208**. Capture tube **1224** may be peeled away from shaft **1232** by severing the perforated region **1245**. Radiopaque markers may be placed at different locations on the shaft **1232**, often near the balloon **1240** or stent **1242**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIGS. **13**A, **14**A, **15**A, and **16**A illustrates a zipper that allows one catheter to snap in to the other catheter. The zipper is essentially a groove that forms a concave receiving cross section and is carved into a catheter's outer surface in a straight line. The groove can be a single groove over a certain portion of a catheter or it can run from end to end. Alternatively, the catheter can have a series of short grooves of 1 to 10 centimeters in length that run the length of the catheter or only a certain portion. Full length end to end zippers will have reduced profile and reduced friction with the vessel. The resulting groove can receive another catheter and prevent the catheters from dislodging while the operator is advancing the catheters to the bifurcation. Once at the site the operator can still slidably move the catheters forward and back relative to each other. Mother catheters that utilize the groove can have fully crimped stents as described in several of the embodiments above; however, it is possible to allow operators to choose any commercially available catheter with or without a stent and mount the commercially available catheter via the zipper. The mother catheters with an empty zipper would have a mother stent fully crimped on the distal balloon portion. After loading the commercially available catheter the operator would have to crimp the proximal portion of the mother stent in situ prior to begin-

ning the clinical procedure. This option may be extremely valuable to operators who can reduce their total inventory of catheters but have more options for treating bifurcated lesions.

FIG. **13**A illustrates a catheter system **1300** having a distal daughter catheter with an over the wire design and a proximal mother catheter with a rapid exchange design and a short zipper. FIG. **13**B more clearly illustrates the features of the catheter system **1300** in FIG. **13**A. The stent delivery system **1300** includes a first catheter **1302**, and a second catheter **1330**. The first catheter **1302** includes an elongate shaft **1304** with a radially expandable balloon **1306** disposed near a distal end of the elongate shaft **1304**. A stent **1308** having a proximal portion **1322**, a distal portion **1314** and a side hole **1320** is disposed over the balloon **1306**. The distal portion **1314** is crimped to the balloon **1306** to prevent ejection during delivery, while the proximal portion **1322** is partially crimped to the balloon **1306** so the second catheter **1330** may be slidably advanced under the proximal portion **1322** of stent **1308**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1312** extending from the distal guidewire port **1310** at the distal end of the elongate shaft **1304** to the proximal end of the elongate shaft **1304** into Y-adapter **1314** having a connector **1316**. The connector **1316** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1312** exits via connector **1316**. A second connector **1318**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1306** via an inflation lumen (not shown) in the elongate shaft **1304**. The first catheter **1302** also includes a zipper or snap fitting **1324** coupled to the elongate shaft **1304**. The snap fit tube **1324** may be coextruded with the first shaft **1304**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1324** may alternatively be coupled with the other shaft **1332**. The snap fitting **1324** includes a central channel **1326** extending therethrough and is sized to slidably receive a portion of the second catheter **1330**. An elongate slot **1345** extends along the entire length of the snap fitting **1324** and is sized so that shaft **1336** may snapped into the central channel **1326**. FIG. **13**C illustrates a partial cross-section of FIG. **13**B taken along the line C-C and shows shaft **1304** with the snap fitting **1324**. Radiopaque markers may be placed at different locations along the shaft **1304**, often near the balloon **1306** and/or stent **1308**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **1330** includes an elongate shaft **1332** with a radially expandable balloon **1340** disposed near a distal end of the elongate shaft **1332**. A stent **1342** is disposed over balloon **1340**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1342** is shorter than the working length of the balloon **1340** so that a proximal portion of the balloon **1340** is unconstrained by the stent **1342** and this unconstrained portion of the balloon **1340** may be slidably advanced or retracted through side hole **1320** and under proximal portion **1322** of stent **1308** as will be discussed below. Stent **1342** is crimped to balloon **1340** to prevent ejection during delivery. At least a portion of balloon **1340**, and stent **1342** are distally offset relative to balloon **1306** and stent **1308** so as to minimize profile of the device. In this embodiment the distal stent **1342** may be deployed in a main branch of the vessel and the other stent **1308** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1342** may be deployed in a side branch of a vessel and the other stent **1308** may be deployed in the main branch of a vessel. The second catheter **1330** is a rapid exchange catheter (RX) having a guidewire lumen **1334** extending from the distal guidewire port **1338** at the distal end of the elongate shaft **1332** to a proximal guidewire port **1336** which is closer to the distal port **1338** than the proximal end of the catheter shaft **1332**. The proximal guidewire port **1336** is also unobstructed by the snap fitting **1324** and preferably proximal thereto. A connector **1344**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1332** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1332** for inflation of balloon **1340**. A portion of shaft **1332** is snapped into the central channel **1326** of the snap fitting **1324** via slit **1345**, and thus shaft **1332** may slide in channel **1326**. This helps keep the two catheter shafts **1304**, **1332** parallel and prevents tangling during delivery and as shaft **1332** is slidably advanced or retracted relative to shaft **1304**. Also, another portion of shaft **1332** is disposed under proximal portion **1322** of stent **1308**. The second catheter **1330** may also be slidably advanced or refracted under the proximal portion **1322** of stent **1308** so that the shaft **1332** passes through the side hole **1320** in stent **1308**. Radiopaque markers may be placed at different locations on the shaft **1332**, often near the balloon **1340** or stent **1342**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **14**A illustrates a catheter system **1400** having a proximal mother catheter with a rapid exchange configuration and a distal daughter catheter having an over-the-wire configuration and a short zipper or snap fitting. FIG. **14**B more clearly illustrates the features of the catheter system **1400** in FIG. **14**A. The stent delivery system **1400** includes a first catheter **1402**, and a second catheter **1430**. The first catheter **1402** includes an elongate shaft **1404** with a radially expandable balloon **1406** disposed near a distal end of the elongate shaft **1404**, and a stent **1408** disposed over the balloon **1406**. The stent **1408** may be the same length as the working length of the balloon **1408**, or it may be shorter. In preferred embodiments, the stent **1408** is shorter than the working length of balloon **1406** such that a proximal portion of balloon **1406** remains unconstrained by stent **1408**. The proximal portion of balloon **1406** may be slidably advanced and retracted under stent **1442** via side hole **1420**. Stent **1408** is crimped to the balloon **1406** to prevent ejection during delivery. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1412** extending from the distal guidewire port **1410** at the distal end of the elongate shaft **1404** to the proximal end of the elongate shaft **1404** into Y-adapter **1414** having a connector **1416**. The connector **1416** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1412** exits via connector **1416**. A second connector **1418**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1406** via an inflation lumen (not shown) in the elongate shaft **1404**. The first catheter **1402** also includes a zipper or snap fitting **1424** coupled to the elongate shaft **1404**. The snap fit tube **1424** may be coextruded with the first shaft **1404**, or it may be bonded or

otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1424** may alternatively be coupled with the other shaft **1432**. The snap fitting **1424** includes a central channel **1426** extending therethrough and is sized to slidably receive a portion of the second catheter **1430**. An elongate slot **1445** extends along the entire length of the snap fitting **1424** and is sized so that shaft **1436** may be snapped into the central channel **1426**. FIG. **14**C illustrates a partial cross-section of FIG. **14**B taken along the line C-C and shows shaft **1404** with the snap fitting **1424**. Radiopaque markers may be placed at different locations along the shaft **1404**, often near the balloon **1406** and/or stent **1408**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **1430** includes an elongate shaft **1432** with a radially expandable balloon **1440** disposed near a distal end of the elongate shaft **1432**. A stent **1442** having a proximal portion **1422**, a distal portion **1414**, and a side hole **1420** is disposed over balloon **1440**. The distal portion **1414** is crimped to balloon **1440** to prevent ejection during delivery, while the proximal portion **1422** is partially crimped to balloon **1440** so elongate shaft **1404** may be slidably advanced or retracted under the proximal portion **1422** of stent **1442**. The stent may preferably have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. At least a portion of balloon **1406**, and stent **1408** are distally offset relative to balloon **1440** and stent **1442** so as to minimize profile of the device. In this embodiment the distal stent **1408** may be deployed in a main branch of the vessel and the other stent **1442** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1408** may be deployed in a side branch of a vessel and the other stent **1442** may be deployed in the main branch of a vessel. The second catheter **1430** is a rapid exchange catheter (RX) having a guidewire lumen **1434** extending from the distal guidewire port **1438** at the distal end of the elongate shaft **1432** to a proximal guidewire port **1436** which is closer to the distal port **1438** than the proximal end of the catheter shaft **1432**. The proximal guidewire port **1436** is also unobstructed by the snap fitting **1424** and preferably proximal thereto. A connector **1444**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1432** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1432** for inflation of balloon **1440**. A portion of shaft **1432** is snapped into the central channel **1426** of the snap fitting **1424** via slit **1445**, and thus shaft **1432** may slide in channel **1426**. This helps keep the two catheter shafts **1404**, **1432** parallel and prevents tangling during delivery and as shaft **1432** is slidably advanced or retracted relative to shaft **1404**. Also, a portion of shaft **1404** is disposed under proximal portion **1422** of stent **1442**. The first catheter **1402** may be slidably advanced or retracted under the proximal portion **1422** of stent **1442** so that the shaft **1404** passes through the side hole **1420** in stent **1442**. Radiopaque markers may be placed at different locations on the shaft **1432**, often near the balloon **1440** or stent **1442**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **15**A illustrates a catheter system **1500** having dual rapid exchange design with a short zipper or snap fitting. FIG. **15**B more clearly illustrates the features of the catheter system **1500** in FIG. **15**A. The stent delivery system **1500** includes a first catheter **1502**, and a second catheter **1530**. The first catheter **1502** includes an elongate shaft **1504** with a radially expandable balloon **1506** disposed near a distal end of the elongate shaft **1504**. A stent **1508** having a proximal portion **1522**, a distal portion **1514** and a side hole **1520** is disposed over the balloon **1506**. The distal portion **1514** is crimped to the balloon **1506** to prevent ejection during delivery, while the proximal portion **1522** is partially crimped to the balloon **1506** so the second catheter **1530** may be slidably advanced under the proximal portion **1522** of stent **1508**. The first catheter is a rapid exchange catheter (RX) having a guidewire lumen **1512** extending from the distal guidewire port **1510** at the distal end of the elongate shaft **1504** to a proximal guidewire port **1511** which is closer to the distal port **1510** than the proximal end of the catheter shaft **1504**. A connector **1516** is coupled with the proximal end of the elongate shaft **1504**. The connector **1516** is preferably a Luer connector and this allows easy coupling with an Indeflator or other device for inflation of the balloon **1506**. The first catheter **1502** also includes a zipper or snap fitting **1524** coupled to the elongate shaft **1504**. The snap fit tube **1524** may be coextruded with the first shaft **1504**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1524** may alternatively be coupled with the other shaft **1532**. The snap fitting **1524** includes a central channel **1526** extending therethrough and is sized to slidably receive a portion of the second catheter **1530**. An elongate slot **1545** extends along the entire length of the snap fitting **1524** and is sized so that shaft **1536** may snapped into the central channel **1526**. FIG. **15**C illustrates a partial cross-section of FIG. **15**B taken along the line C-C and shows shaft **1504** with the snap fitting **1524**. Radiopaque markers may be placed at different locations along the shaft **1504**, often near the balloon **1506** and/or stent **1508**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **1530** includes an elongate shaft **1532** with a radially expandable balloon **1540** disposed near a distal end of the elongate shaft **1532**. A stent **1542** is disposed over balloon **1540**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1542** is shorter than the working length of the balloon **1540** so that a proximal portion of the balloon **1540** is unconstrained by the stent **1542** and this unconstrained portion of the balloon **1540** may be slidably advanced or retracted through side hole **1520** and under proximal portion **1522** of stent **1508** as will be discussed below. Stent **1542** is crimped to balloon **1540** to prevent ejection during delivery. At least a portion of balloon **1540**, and stent **1542** are distally offset relative to balloon **1506** and stent **1508** so as to minimize profile of the device. In this embodiment the distal stent **1542** may be deployed in a main branch of the vessel and the other stent **1508** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1542** may be deployed in a side branch of a vessel and the other stent **1508** may be deployed in the main branch of a vessel. The second catheter **1530** is a rapid exchange catheter (RX) having a guidewire lumen **1534** extending from the distal guidewire port **1538** at the distal end of the elongate shaft **1532** to a proximal guidewire port **1536** which is closer to the distal port **1538** than the proximal end of the catheter shaft **1532**. The proximal guidewire port **1536** is also unobstructed by the snap fitting **1524** and may be distal thereto. A connector **1544**, prefer-

ably a Luer connector is connected to the proximal end of the elongate shaft **1532** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1532** for inflation of balloon **1540**. A portion of shaft **1532** is snapped into the central channel **1526** of the snap fitting **1524** via slit **1545**, and thus shaft **1532** may slide in channel **1526**. This helps keep the two catheter shafts **1504**, **1532** parallel and prevents tangling during delivery and as shaft **1532** is slidably advanced or retracted relative to shaft **1504**. Also, another portion of shaft **1532** is disposed under proximal portion **1522** of stent **1508**. The second catheter **1530** may also be slidably advanced or retracted under the proximal portion **1522** of stent **1508** so that the shaft **1532** passes through the side hole **1520** in stent **1508**. Radiopaque markers may be placed at different locations on the shaft **1532**, often near the balloon **1540** or stent **1542**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **16**A illustrates a catheter system **1600** having a dual over the wire design with a short zipper or snap fitting. FIG. **16**B more clearly illustrates the features of the catheter system **1600** in FIG. **16**A. The stent delivery system **1600** includes a first catheter **1602**, and a second catheter **1630**. The first catheter **1602** includes an elongate shaft **1604** with a radially expandable balloon **1606** disposed near a distal end of the elongate shaft **1604**. A stent **1608** having a proximal portion **1622**, a distal portion **1614** and a side hole **1620** is disposed over the balloon **1606**. The distal portion **1614** is crimped to the balloon **1606** to prevent ejection during delivery, while the proximal portion **1622** is partially crimped to the balloon **1606** so the second catheter **1630** may be slidably advanced under the proximal portion **1622** of stent **1608**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1612** extending from the distal guidewire port **1610** at the distal end of the elongate shaft **1604** to the proximal end of the elongate shaft **1604** into Y-adapter **1614** having a connector **1616**. The connector **1616** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1612** exits via connector **1616**. A second connector **1618**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1606** via an inflation lumen (not shown) in the elongate shaft **1604**. The first catheter **1602** also includes a zipper or snap fitting **1624** coupled to the elongate shaft **1604**. The snap fit tube **1624** may be coextruded with the first shaft **1604**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1624** may alternatively be coupled with the other shaft **1632**. The snap fitting **1624** includes a central channel **1626** extending therethrough and is sized to slidably receive a portion of the second catheter **1630**. An elongate slot **1645** extends along the entire length of the snap fitting **1624** and is sized so that shaft **1636** may snapped into the central channel **1626**. FIG. **16**C illustrates a partial cross-section of FIG. **16**B taken along the line C-C and shows shaft **1604** with the snap fitting **1624**. Radiopaque markers may be placed at different locations along the shaft **1604**, often near the balloon **1606** and/or stent **1608**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **1630** includes an elongate shaft **1632** with a radially expandable balloon **1640** disposed near a distal end of the elongate shaft **1632**. A stent **1642** is disposed over balloon **1640**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1642** is shorter than the working length of the balloon **1640** so that a proximal portion of the balloon **1640** is unconstrained by the stent **1642** and this unconstrained portion of the balloon **1640** may be slidably advanced or retracted through side hole **1620** and under proximal portion **1622** of stent **1608** as will be discussed below. Stent **1642** is crimped to balloon **1640** to prevent ejection during delivery. At least a portion of balloon **1640**, and stent **1642** are distally offset relative to balloon **1606** and stent **1608** so as to minimize profile of the device. In this embodiment the distal stent **1642** may be deployed in a main branch of the vessel and the other stent **1608** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1642** may be deployed in a side branch of a vessel and the other stent **1608** may be deployed in the main branch of a vessel. The second catheter **1630** is an over-the-wire (OTW) catheter having a guidewire lumen **1634** extending from the distal guidewire port **1638** at the distal end of the elongate shaft **1632** to the proximal end of the elongate shaft **1632** into Y-adapter **1646** having a connector **1648**. The connector **1648** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1634** exits via connector **1648**. A second connector **1644**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1640** via an inflation lumen (not shown) in the elongate shaft **1632**. A portion of shaft **1632** is snapped into the central channel **1626** of the snap fitting **1624** via slit **1645**, and thus shaft **1632** may slide in channel **1626**. This helps keep the two catheter shafts **1604**, **1632** parallel and prevents tangling during delivery and as shaft **1632** is slidably advanced or retracted relative to shaft **1604**. Also, another portion of shaft **1632** is disposed under proximal portion **1622** of stent **1608**. The second catheter **1630** may also be slidably advanced or retracted under the proximal portion **1622** of stent **1608** so that the shaft **1632** passes through the side hole **1620** in stent **1608**. Radiopaque markers may be placed at different locations on the shaft **1632**, often near the balloon **1640** or stent **1642**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **17**A illustrates a catheter system **1700** having a distal daughter catheter with a rapid exchange configuration a proximal mother catheter with an over-the-wire configuration and an end to end zipper, or snap fitting. This embodiment is similar to that shown in FIG. **13**A-**13**B, with the major difference being the length of the snap fitting and the location of one of the guidewire ports. FIG. **17**B more clearly illustrates the features of the catheter system **1700** in FIG. **17**A. The stent delivery system **1700** includes a first catheter **1702**, and a second catheter **1730**. The first catheter **1702** includes an elongate shaft **1704** with a radially expandable balloon **1706** disposed near a distal end of the elongate shaft **1704**. A stent **1708** having a proximal portion **1722**, a distal portion **1714** and a side hole **1720** is disposed over the balloon **1706**. The distal portion **1714** is crimped to the balloon **1706** to prevent ejection during delivery, while the proximal portion **1722** is partially crimped to the balloon **1706** so the second catheter **1730** may be slidably advanced under the proximal portion **1722** of stent **1708**. The first

catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1712** extending from the distal guidewire port **1710** at the distal end of the elongate shaft **1704** to the proximal end of the elongate shaft **1704** into Y-adapter **1714** having a connector **1716**. The connector **1716** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1712** exits via connector **1716**. A second connector **1718**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1706** via an inflation lumen (not shown) in the elongate shaft **1704**. The first catheter **1702** also includes a zipper or snap fitting **1724** coupled to the elongate shaft **1704**. The snap fit tube **1724** may be coextruded with the first shaft **1704**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1724** may alternatively be coupled with the other shaft **1732**. The snap fitting **1724** includes a central channel **1726** extending therethrough and is sized to slidably receive a portion of the second catheter **1730**. An elongate slot **1745** extends along the entire length of the snap fitting **1724** and is sized so that shaft **1736** may snapped into the central channel **1726**. The snap fitting **1724** may extend from the distal end of connectors **1714**, **1744** to the proximal end of balloon **1706**, or it may be shorter, extending only partially between the connectors **1714**, **1744** and the balloon **1706**. FIG. **17**C illustrates a partial cross-section of FIG. **17**B taken along the line C-C and shows shaft **1704** with the snap fitting **1724**. Radiopaque markers may be placed at different locations along the shaft **1704**, often near the balloon **1706** and/or stent **1708**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **1730** includes an elongate shaft **1732** with a radially expandable balloon **1740** disposed near a distal end of the elongate shaft **1732**. A stent **1742** is disposed over balloon **1740**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1742** is shorter than the working length of the balloon **1740** so that a proximal portion of the balloon **1740** is unconstrained by the stent **1742** and this unconstrained portion of the balloon **1740** may be slidably advanced or retracted through side hole **1720** and under proximal portion **1722** of stent **1708** as will be discussed below. Stent **1742** is crimped to balloon **1740** to prevent ejection during delivery. At least a portion of balloon **1740**, and stent **1742** are distally offset relative to balloon **1706** and stent **1708** so as to minimize profile of the device. In this embodiment the distal stent **1742** may be deployed in a main branch of the vessel and the other stent **1708** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1742** may be deployed in a side branch of a vessel and the other stent **1708** may be deployed in the main branch of a vessel. The second catheter **1730** is a rapid exchange catheter (RX) having a guidewire lumen **1734** extending from the distal guidewire port **1738** at the distal end of the elongate shaft **1732** to a proximal guidewire port **1736** which is closer to the distal port **1738** than the proximal end of the catheter shaft **1732**. The proximal guidewire port **1736** is also unobstructed by the snap fitting **1724** and preferably distal thereto. A connector **1744**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1732** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1732** for inflation of balloon **1740**. A portion of shaft **1732** is snapped into the central channel **1726** of the snap fitting **1724** via slit **1745**, and thus shaft **1732** may slide in channel **1726**. This helps keep the two catheter shafts **1704**, **1732** parallel and prevents tangling during delivery and as shaft **1732** is slidably advanced or retracted relative to shaft **1704**. Also, another portion of shaft **1732** is disposed under proximal portion **1722** of stent **1708**. The second catheter **1730** may also be slidably advanced or retracted under the proximal portion **1722** of stent **1708** so that the shaft **1732** passes through the side hole **1720** in stent **1708**. Radiopaque markers may be placed at different locations on the shaft **1732**, often near the balloon **1740** or stent **1742**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **18**A illustrates a catheter system **1800** having a proximal mother catheter with a rapid exchange configuration and a distal daughter catheter with an end to end zipper or snap fitting. FIG. **18**A is similar to the embodiment of FIG. **14**A-**14**B, with the major difference being the length of the snap fitting and the location of one of the guidewire ports. FIG. **18**B more clearly illustrates the features of the catheter system **1800** in FIG. **18**A. The stent delivery system **1800** includes a first catheter **1802**, and a second catheter **1830**. The first catheter **1802** includes an elongate shaft **1804** with a radially expandable balloon **1806** disposed near a distal end of the elongate shaft **1804**, and a stent **1808** disposed over the balloon **1806**. The stent **1808** may be the same length as the working length of the balloon **1808**, or it may be shorter. In preferred embodiments, the stent **1808** is shorter than the working length of balloon **1806** such that a proximal portion of balloon **1806** remains unconstrained by stent **1808**. The proximal portion of balloon **1806** may be slidably advanced and retracted under stent **1842** via side hole **1820**. Stent **1808** is crimped to the balloon **1806** to prevent ejection during delivery. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **1812** extending from the distal guidewire port **1810** at the distal end of the elongate shaft **1804** to the proximal end of the elongate shaft **1804** into Y-adapter **1814** having a connector **1816**. The connector **1816** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **1812** exits via connector **1816**. A second connector **1818**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **1806** via an inflation lumen (not shown) in the elongate shaft **1804**. The first catheter **1802** also includes a zipper or snap fitting **1824** coupled to the elongate shaft **1804**. The snap fit tube **1824** may be coextruded with the first shaft **1804**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1824** may alternatively be coupled with the other shaft **1832**. The snap fitting **1824** includes a central channel **1826** extending therethrough and is sized to slidably receive a portion of the second catheter **1830**. An elongate slot **1845** extends along the entire length of the snap fitting **1824** and is sized so that shaft **1836** may snapped into the central channel **1826**. FIG. **18**C illustrates a partial cross-section of FIG. **18**B taken along the line C-C and shows shaft **1804** with the snap fitting **1824**. The snap fitting **1824** may extend from the distal end of connectors **1814**, **1844** to the proximal end of balloon **1840**, or it may be shorter, extending only partially between the connectors **1814**, **1844** and the balloon **1806**.

Radiopaque markers may be placed at different locations along the shaft **1804**, often near the balloon **1806** and/or stent **1808**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **1830** includes an elongate shaft **1832** with a radially expandable balloon **1840** disposed near a distal end of the elongate shaft **1832**. A stent **1842** having a proximal portion **1822**, a distal portion **1814**, and a side hole **1820** is disposed over balloon **1840**. The distal portion **1814** is crimped to balloon **1840** to prevent ejection during delivery, while the proximal portion **1822** is partially crimped to balloon **1840** so elongate shaft **1804** may be slidably advanced or retracted under the proximal portion **1822** of stent **1842**. The stent may preferably have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. At least a portion of balloon **1806**, and stent **1808** are distally offset relative to balloon **1840** and stent **1842** so as to minimize profile of the device. In this embodiment the distal stent **1808** may be deployed in a main branch of the vessel and the other stent **1842** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1808** may be deployed in a side branch of a vessel and the other stent **1842** may be deployed in the main branch of a vessel. The second catheter **1830** is a rapid exchange catheter (RX) having a guidewire lumen **1834** extending from the distal guidewire port **1838** at the distal end of the elongate shaft **1832** to a proximal guidewire port **1836** which is closer to the distal port **1838** than the proximal end of the catheter shaft **1832**. The proximal guidewire port **1836** is also unobstructed by the snap fitting **1824** and preferably distal thereto. A connector **1844**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1832** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1832** for inflation of balloon **1840**. A portion of shaft **1832** is snapped into the central channel **1826** of the snap fitting **1824** via slit **1845**, and thus shaft **1832** may slide in channel **1826**. This helps keep the two catheter shafts **1804**, **1832** parallel and prevents tangling during delivery and as shaft **1832** is slidably advanced or retracted relative to shaft **1804**. Also, a portion of shaft **1804** is disposed under proximal portion **1822** of stent **1842**. The first catheter **1802** may be slidably advanced or retracted under the proximal portion **1822** of stent **1842** so that the shaft **1804** passes through the side hole **1820** in stent **1842**. Radiopaque markers may be placed at different locations on the shaft **1832**, often near the balloon **1840** or stent **1842**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **19**A illustrates a catheter system **1900** having a dual rapid exchange design with an end to end zipper or snap fitting. FIG. **19**A is similar to the embodiment of FIG. **15**A-**15**B, with the major difference being the length of the snap fitting. FIG. **19**B more clearly illustrates the features of the catheter system **1900** in FIG. **19**A. The stent delivery system **1900** includes a first catheter **1902**, and a second catheter **1930**. The first catheter **1902** includes an elongate shaft **1904** with a radially expandable balloon **1906** disposed near a distal end of the elongate shaft **1904**. A stent **1908** having a proximal portion **1922**, a distal portion **1914** and a side hole **1920** is disposed over the balloon **1906**. The distal portion **1914** is crimped to the balloon **1906** to prevent ejection during delivery, while the proximal portion **1922** is partially crimped to the balloon **1906** so the second catheter **1930** may be slidably advanced under the proximal portion **1922** of stent **1908**. The first catheter is a rapid exchange catheter (RX) having a guidewire lumen **1912** extending from the distal guidewire port **1910** at the distal end of the elongate shaft **1904** to a proximal guidewire port **1911** which is closer to the distal port **1910** than the proximal end of the catheter shaft **1904**. A connector **1916** is coupled with the proximal end of the elongate shaft **1904**. The connector **1916** is preferably a Luer connector and this allows easy coupling with an Indeflator or other device for inflation of the balloon **1906**. The first catheter **1902** also includes a zipper or snap fitting **1924** coupled to the elongate shaft **1904**. The snap fit tube **1924** may be coextruded with the first shaft **1904**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **1924** may alternatively be coupled with the other shaft **1932**. The snap fitting **1924** includes a central channel **1926** extending therethrough and is sized to slidably receive a portion of the second catheter **1930**. An elongate slot **1945** extends along the entire length of the snap fitting **1924** and is sized so that shaft **1932** may snapped into the central channel **1926**. FIG. **19**C illustrates a partial cross-section of FIG. **19**B taken along the line C-C and shows shaft **1904** with the snap fitting **1924**. Radiopaque markers may be placed at different locations along the shaft **1904**, often near the balloon **1906** and/or stent **1908**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **1930** includes an elongate shaft **1932** with a radially expandable balloon **1940** disposed near a distal end of the elongate shaft **1932**. A stent **1942** is disposed over balloon **1940**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **1942** is shorter than the working length of the balloon **1940** so that a proximal portion of the balloon **1940** is unconstrained by the stent **1942** and this unconstrained portion of the balloon **1940** may be slidably advanced or retracted through side hole **1920** and under proximal portion **1922** of stent **1908** as will be discussed below. Stent **1942** is crimped to balloon **1940** to prevent ejection during delivery. At least a portion of balloon **1940**, and stent **1942** are distally offset relative to balloon **1906** and stent **1908** so as to minimize profile of the device. In this embodiment the distal stent **1942** may be deployed in a main branch of the vessel and the other stent **1908** may be deployed in a side branch of the vessel. Alternatively, the distal stent **1942** may be deployed in a side branch of a vessel and the other stent **1908** may be deployed in the main branch of a vessel. The second catheter **1930** is a rapid exchange catheter (RX) having a guidewire lumen **1934** extending from the distal guidewire port **1938** at the distal end of the elongate shaft **1932** to a proximal guidewire port **1936** which is closer to the distal port **1938** than the proximal end of the catheter shaft **1932**. The proximal guidewire port **1936** is also unobstructed by the snap fitting **1924** and may be distal thereto. A connector **1944**, preferably a Luer connector is connected to the proximal end of the elongate shaft **1932** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **1932** for inflation of balloon **1940**. A portion of shaft **1932** is snapped into the central channel **1926** of the snap fitting **1924** via slit **1945**, and thus shaft **1932** may slide in channel **1926**. This helps keep the two catheter shafts **1904**, **1932** parallel and prevents tangling during delivery

and as shaft **1932** is slidably advanced or retracted relative to shaft **1904**. Also, another portion of shaft **1932** is disposed under proximal portion **1922** of stent **1908**. The second catheter **1930** may also be slidably advanced or retracted under the proximal portion **1922** of stent **1908** so that the shaft **1932** passes through the side hole **1920** in stent **1908**. Radiopaque markers may be placed at different locations on the shaft **1932**, often near the balloon **1940** or stent **1942**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **20**A illustrates a catheter system **2000** having a dual over the wire design with an end to end zipper or snap fitting. FIG. **20**A is similar to the embodiment of FIG. **16**A-**16**B, with the major difference being the length of the snap fitting. FIG. **20**B more clearly illustrates the features of the catheter system **2000** in FIG. **20**A. The stent delivery system **2000** includes a first catheter **2002**, and a second catheter **2030**. The first catheter **2002** includes an elongate shaft **2004** with a radially expandable balloon **2006** disposed near a distal end of the elongate shaft **2004**. A stent **2008** having a proximal portion **2022**, a distal portion **2014** and a side hole **2020** is disposed over the balloon **2006**. The distal portion **2014** is crimped to the balloon **2006** to prevent ejection during delivery, while the proximal portion **2022** is partially crimped to the balloon **2006** so the second catheter **2030** may be slidably advanced under the proximal portion **2022** of stent **2008**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **2012** extending from the distal guidewire port **2010** at the distal end of the elongate shaft **2004** to the proximal end of the elongate shaft **2004** into Y-adapter **2014** having a connector **2016**. The connector **2016** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **2012** exits via connector **2016**. A second connector **2018**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **2006** via an inflation lumen (not shown) in the elongate shaft **2004**. The first catheter **2002** also includes a zipper or snap fitting **2024** coupled to the elongate shaft **2004**. The snap fit tube **2024** may be coextruded with the first shaft **2004**, or it may be bonded or otherwise attached thereto using techniques known to those skilled in the art. The snap fit **2024** may alternatively be coupled with the other shaft **2032**. The snap fitting **2024** includes a central channel **2026** extending therethrough and is sized to slidably receive a portion of the second catheter **2030**. An elongate slot **2045** extends along the entire length of the snap fitting **2024** and is sized so that shaft **2036** may snapped into the central channel **2026**. FIG. **20**C illustrates a partial cross-section of FIG. **20**B taken along the line C-C and shows shaft **2004** with the snap fitting **2024**. Radiopaque markers may be placed at different locations along the shaft **2004**, often near the balloon **2006** and/or stent **2008**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **2030** includes an elongate shaft **2032** with a radially expandable balloon **2040** disposed near a distal end of the elongate shaft **2032**. A stent **2042** is disposed over balloon **2040**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **2042** is shorter than the working length of the balloon **2040** so that a proximal portion of the balloon **2040** is unconstrained by the stent **2042** and this unconstrained portion of the balloon **2040** may be slidably advanced or retracted through side hole **2020** and under proximal portion **2022** of stent **2008** as will be discussed below. Stent **2042** is crimped to balloon **2040** to prevent ejection during delivery. At least a portion of balloon **2040**, and stent **2042** are distally offset relative to balloon **2006** and stent **2008** so as to minimize profile of the device. In this embodiment the distal stent **2042** may be deployed in a main branch of the vessel and the other stent **2008** may be deployed in a side branch of the vessel. Alternatively, the distal stent **2042** may be deployed in a side branch of a vessel and the other stent **2008** may be deployed in the main branch of a vessel. The second catheter **2030** is an over-the-wire (OTW) catheter having a guidewire lumen **2034** extending from the distal guidewire port **2038** at the distal end of the elongate shaft **2032** to the proximal end of the elongate shaft **2032** into Y-adapter **2046** having a connector **2048**. The connector **2048** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **2034** exits via connector **2048**. A second connector **2044**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **2040** via an inflation lumen (not shown) in the elongate shaft **2032**. A portion of shaft **2032** is snapped into the central channel **2026** of the snap fitting **2024** via slit **2045**, and thus shaft **2032** may slide in channel **2026**. This helps keep the two catheter shafts **2004**, **2032** parallel and prevents tangling during delivery and as shaft **2032** is slidably advanced or retracted relative to shaft **2004**. Also, another portion of shaft **2032** is disposed under proximal portion **2022** of stent **2008**. The second catheter **2030** may also be slidably advanced or retracted under the proximal portion **2022** of stent **2008** so that the shaft **2032** passes through the side hole **2020** in stent **2008**. Radiopaque markers may be placed at different locations on the shaft **2032**, often near the balloon **2040** or stent **2042**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIGS. **21**A, **22**A, **23**A, and **24**A illustrate catheters that can be used with an alternative embodiment where the mother catheter is provided to the operator with a mother stent that is crimped on the distal portion of the mother catheter balloon. The proximal portion of the mother stent is uncrimped or partially crimped. The operator can mount any commercially available catheter or balloon on a wire through the mother stent proximal end and exit out the side hole of the mother stent. The operator can align the catheters to suit the patient's anatomy and crimp the proximal portion of the mother stent. The operator can crimp the stent tightly so that the catheters do not move relative to each other. It is possible for the operator to place the catheters at the bifurcation and if necessary pullback on the commercially available catheter to adjust the alignment if necessary. Then the operator can gently push the system distally to ensure complete apposition.

FIG. **21**A illustrates a catheter system **2100** having a distal daughter catheter with a rapid exchange configuration and a proximal mother catheter with an over-the-wire configuration. FIG. **21**B more clearly illustrates the features of the catheter system **2100** in FIG. **21**A. The stent delivery system **2100** includes a first catheter **2102**, and a second catheter **2130**. The first catheter **2102** includes an elongate shaft **2104** with a radially expandable balloon **2106** disposed near a

distal end of the elongate shaft **2104**. A stent **2108** having a proximal portion **2122**, a distal portion **2114** and a side hole **2120** is disposed over the balloon **2106**. The distal portion **2114** is crimped to the balloon **2106** to prevent ejection during delivery, while the proximal portion **2122** is partially crimped to the balloon **2106** so the second catheter **2130** may be slidably advanced under the proximal portion **2122** of stent **2108**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **2112** extending from the distal guidewire port **2110** at the distal end of the elongate shaft **2104** to the proximal end of the elongate shaft **2104** into Y-adapter **2114** having a connector **2116**. The connector **2116** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **2112** exits via connector **2116**. A second connector **2118**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **2106** via an inflation lumen (not shown) in the elongate shaft **2104**. Radiopaque markers may be placed at different locations along the shaft **2104**, often near the balloon **2106** and/or stent **2108**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **2130** includes an elongate shaft **2132** with a radially expandable balloon **2140** disposed near a distal end of the elongate shaft **2132**. A stent **2142** is disposed over balloon **2140**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **2142** is shorter than the working length of the balloon **2140** so that a proximal portion of the balloon **2140** is unconstrained by the stent **2142** and this unconstrained portion of the balloon **2140** may be slidably advanced or retracted through side hole **2120** and under proximal portion **2122** of stent **2108** as will be discussed below. Stent **2142** is crimped to balloon **2140** to prevent ejection during delivery. At least a portion of balloon **2140**, and stent **2142** are distally offset relative to balloon **2106** and stent **2108** so as to minimize profile of the device. In this embodiment the distal stent **2142** may be deployed in a main branch of the vessel and the other stent **2108** may be deployed in a side branch of the vessel. Alternatively, the distal stent **2142** may be deployed in a side branch of a vessel and the other stent **2108** may be deployed in the main branch of a vessel. The second catheter **2130** is a rapid exchange catheter (RX) having a guidewire lumen **2134** extending from the distal guidewire port **2138** at the distal end of the elongate shaft **2132** to a proximal guidewire port **2136** which is closer to the distal port **2138** than the proximal end of the catheter shaft **2132**. A connector **2144**, preferably a Luer connector is connected to the proximal end of the elongate shaft **2132** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **2132** for inflation of balloon **2140**. Having a portion of shaft **2132** disposed under proximal portion **2122** of stent **2108** helps keep catheter **2104**, **2132** parallel and prevents tangling during delivery and as shaft **2132** is slidably advanced or retracted relative to shaft **2104**. Also, another portion of shaft **2132** is disposed under proximal portion **2122** of stent **2108**. The second catheter **2130** may also be slidably advanced or retracted under the proximal portion **2122** of stent **2108** so that the shaft **2132** passes through the side hole **2120** in stent **2108**. Radiopaque markers may be placed at different locations on the shaft **2132**, often near the balloon **2140** or stent **2142**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **22**A illustrates a catheter system **2200** having a proximal mother catheter with an over the wire design and a distal daughter catheter with an over-the-wire configuration. FIG. **22**B more clearly illustrates the features of the catheter system **2200** in FIG. **22**A. The stent delivery system **2200** includes a first catheter **2202**, and a second catheter **2230**. The first catheter **2202** includes an elongate shaft **2204** with a radially expandable balloon **2206** disposed near a distal end of the elongate shaft **2204**, and a stent **2208** disposed over the balloon **2206**. The stent **2208** may be the same length as the working length of the balloon **2208**, or it may be shorter. In preferred embodiments, the stent **2208** is shorter than the working length of balloon **2206** such that a proximal portion of balloon **2206** remains unconstrained by stent **2208**. The proximal portion of balloon **2206** may be slidably advanced and retracted under stent **2242** via side hole **2220**. Stent **2208** is crimped to the balloon **2206** to prevent ejection during delivery. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **2212** extending from the distal guidewire port **2210** at the distal end of the elongate shaft **2204** to the proximal end of the elongate shaft **2204** into Y-adapter **2214** having a connector **2216**. The connector **2216** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **2212** exits via connector **2216**. A second connector **2218**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **2206** via an inflation lumen (not shown) in the elongate shaft **2204**. Radiopaque markers may be placed at different locations along the shaft **2204**, often near the balloon **2206** and/or stent **2208**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **2230** includes an elongate shaft **2232** with a radially expandable balloon **2240** disposed near a distal end of the elongate shaft **2232**. A stent **2242** having a proximal portion **2222**, a distal portion **2214**, and a side hole **2220** is disposed over balloon **2240**. The distal portion **2214** is crimped to balloon **2240** to prevent ejection during delivery, while the proximal portion **2222** is partially crimped to balloon **2240** so elongate shaft **2204** may be slidably advanced or retracted under the proximal portion **2222** of stent **2242**. The stent may preferably have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. At least a portion of balloon **2206**, and stent **2208** are distally offset relative to balloon **2240** and stent **2242** so as to minimize profile of the device. In this embodiment the distal stent **2208** may be deployed in a main branch of the vessel and the other stent **2242** may be deployed in a side branch of the vessel. Alternatively, the distal stent **2208** may be deployed in a side branch of a vessel and the other stent **2242** may be deployed in the main branch of a vessel. The second catheter **2230** is a rapid exchange catheter (RX) having a guidewire lumen **2234** extending from the distal guidewire port **2238** at the distal end of the elongate shaft **2232** to a proximal guidewire port **2236** which is closer to the distal port **2238** than the proximal end of the catheter shaft **2232**. A connector **2244**, preferably a Luer connector is connected to the proximal end of the elongate shaft **2232** and allows an Indeflator or other device to be coupled with an inflation

lumen (not shown) in elongate shaft **2232** for inflation of balloon **2240**. Having a portion of shaft **2204** disposed under proximal portion **2222** of stent **2208** helps keep catheter shafts **2202**, **2232** parallel and prevents tangling during delivery and as shaft **2204** is slidably advanced or retracted relative to shaft **2232**. The first catheter **2202** may be slidably advanced or retracted under the proximal portion **2222** of stent **2242** so that the shaft **2204** passes through the side hole **2220** in stent **2242**. Radiopaque markers may be placed at different locations on the shaft **2232**, often near the balloon **2240** or stent **2242**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **23**A illustrates a catheter system **2300** having a dual rapid exchange design. FIG. **23**B more clearly illustrates the features of the catheter system **2300** in FIG. **23**A. The stent delivery system **2300** includes a first catheter **2302**, and a second catheter **2330**. The first catheter **2302** includes an elongate shaft **2304** with a radially expandable balloon **2306** disposed near a distal end of the elongate shaft **2304**. A stent **2308** having a proximal portion **2322**, a distal portion **2314** and a side hole **2320** is disposed over the balloon **2306**. The distal portion **2314** is crimped to the balloon **2306** to prevent ejection during delivery, while the proximal portion **2322** is partially crimped to the balloon **2306** so the second catheter **2330** may be slidably advanced under the proximal portion **2322** of stent **2308**. The first catheter is a rapid exchange catheter (RX) having a guidewire lumen **2312** extending from the distal guidewire port **2310** at the distal end of the elongate shaft **2304** to a proximal guidewire port **2311** which is closer to the distal port **2310** than the proximal end of the catheter shaft **2304**. A connector **2316** is coupled with the proximal end of the elongate shaft **2304**. The connector **2116** is preferably a Luer connector and this allows easy coupling with an Indeflator or other device for inflation of the balloon **2306**. Radiopaque markers may be placed at different locations along the shaft **2304**, often near the balloon **2306** and/or stent **2308**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **2330** includes an elongate shaft **2332** with a radially expandable balloon **2340** disposed near a distal end of the elongate shaft **2332**. A stent **2342** is disposed over balloon **2340**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **2342** is shorter than the working length of the balloon **2340** so that a proximal portion of the balloon **2340** is unconstrained by the stent **2342** and this unconstrained portion of the balloon **2340** may be slidably advanced or retracted through side hole **2320** and under proximal portion **2322** of stent **2308** as will be discussed below. Stent **2342** is crimped to balloon **2340** to prevent ejection during delivery. At least a portion of balloon **2340**, and stent **2342** are distally offset relative to balloon **2306** and stent **2308** so as to minimize profile of the device. In this embodiment the distal stent **2342** may be deployed in a main branch of the vessel and the other stent **2308** may be deployed in a side branch of the vessel. Alternatively, the distal stent **2342** may be deployed in a side branch of a vessel and the other stent **2308** may be deployed in the main branch of a vessel. The second catheter **2330** is a rapid exchange catheter (RX) having a guidewire lumen **2334** extending from the distal guidewire port **2338** at the distal end of the elongate shaft **2332** to a proximal guidewire port **2336** which is closer to the distal port **2338** than the proximal end of the catheter shaft **2332**. A connector **2344**, preferably a Luer connector is connected to the proximal end of the elongate shaft **2332** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **2332** for inflation of balloon **2340**. Having a portion of shaft **2332** disposed under proximal portion **2322** of stent **2208** helps keep catheters **2302**, **2332** parallel and prevents tangling during delivery and as shaft **2332** is slidably advanced or retracted relative to shaft **2304**. The second catheter **2330** may also be slidably advanced or retracted under the proximal portion **2322** of stent **2308** so that the shaft **2332** passes through the side hole **2320** in stent **2308**. Radiopaque markers may be placed at different locations on the shaft **2332**, often near the balloon **2340** or stent **2342**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **24**A illustrates a catheter system **2400** having a dual over the wire design. FIG. **24**B more clearly illustrates the features of the catheter system **2400** in FIG. **24**A. The stent delivery system **2400** includes a first catheter **2402**, and a second catheter **2430**. The first catheter **2402** includes an elongate shaft **2404** with a radially expandable balloon **2406** disposed near a distal end of the elongate shaft **2404**. A stent **2408** having a proximal portion **2422**, a distal portion **2414** and a side hole **2420** is disposed over the balloon **2406**. The distal portion **2414** is crimped to the balloon **2406** to prevent ejection during delivery, while the proximal portion **2422** is partially crimped to the balloon **2406** so the second catheter **2430** may be slidably advanced under the proximal portion **2422** of stent **2408**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **2412** extending from the distal guidewire port **2410** at the distal end of the elongate shaft **2404** to the proximal end of the elongate shaft **2404** into Y-adapter **2414** having a connector **2416**. The connector **2416** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **2412** exits via connector **2416**. A second connector **2418**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **2406** via an inflation lumen (not shown) in the elongate shaft **2404**. Radiopaque markers may be placed at different locations along the shaft **2404**, often near the balloon **2406** and/or stent **2408**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **2430** includes an elongate shaft **2432** with a radially expandable balloon **2440** disposed near a distal end of the elongate shaft **2432**. A stent **2442** is disposed over balloon **2440**. The stent may have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. In preferred embodiments, the stent **2442** is shorter than the working length of the balloon **2440** so that a proximal portion of the balloon **2440** is unconstrained by the stent **2442** and this unconstrained portion of the balloon **2440** may be slidably advanced or retracted through side hole **2420** and under proximal portion **2422** of stent **2408** as will be discussed below. Stent **2442** is crimped to balloon **2440** to prevent ejection during delivery. At least a portion of balloon **2440**, and stent **2442** are distally offset relative to balloon **2406** and stent **2408** so as to minimize profile of the device. In this embodiment the distal stent **2442** may be deployed in

a main branch of the vessel and the other stent **2408** may be deployed in a side branch of the vessel. Alternatively, the distal stent **2442** may be deployed in a side branch of a vessel and the other stent **2408** may be deployed in the main branch of a vessel. The second catheter **2430** is an over-the-wire (OTW) catheter having a guidewire lumen **2434** extending from the distal guidewire port **2438** at the distal end of the elongate shaft **2432** to the proximal end of the elongate shaft **2432** into Y-adapter **2446** having a connector **2448**. The connector **2448** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **2434** exits via connector **2448**. A second connector **2444**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **2440** via an inflation lumen (not shown) in the elongate shaft **2432**. Having a portion of shaft **2432** disposed under proximal portion **2422** of stent **2408** helps keep catheters **2402**, **2430** parallel and prevents tangling during delivery and as shaft **2432** is slidably advanced or retracted relative to shaft **2404**. The second catheter **2430** may also be slidably advanced or retracted under the proximal portion **2422** of stent **2408** so that the shaft **2432** passes through the side hole **2420** in stent **2408**. Radiopaque markers may be placed at different locations on the shaft **2432**, often near the balloon **2440** or stent **2442**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

In some embodiments, only a single stent may be deployed at the bifurcation. This "provisional" method of treating the bifurcation stents the main branch of the vessel and provides side branch access without obstructing the ostium to the side branch. FIGS. **40-43** illustrate exemplary embodiments of systems that may be used to provisionally treat a bifurcation. Additionally, any of the features described above, including but not limited to the hollow exchange port, capture tube, locking mechanism, perforated capture tube, polymer sleeve, and snap fit may optionally be included with the embodiments of FIGS. **40-43**, but are not illustrated. Also, any commercially available stent may be used in these systems either as is, or with slight modification. Commercially available dilation catheters may also be mixed and matched with one another.

The embodiments seen in FIGS. **40-43** may be used as described herein, or they may also be used to treat bifurcations according to other methods, such as those disclosed in U.S. patent applications previously incorporated by reference above. For example, in another exemplary use, the embodiments of FIGS. **40-43** may be used for ostial stenting, wherein the single stent is partially delivered and expanded in the main vessel and also partially delivered and expanded in the side branch. FIG. **40** illustrates a stent delivery system **4500**. The stent delivery system **4500** includes a first catheter **4530**, and a second catheter **4502**. The first catheter **4530** includes an elongate shaft **4532** with a radially expandable balloon **4540** disposed near a distal end of the elongate shaft **4532**. A proximal portion of the balloon **4540** may be slidably advanced or retracted through side hole **4520** and under proximal portion **4522** of stent **4508** as will be discussed below. At least a portion of balloon **4540** is distally offset relative to balloon **4506** and stent **4508** so as to minimize profile of the device. In this embodiment the stent **4508** is preferably deployed in a main branch of the vessel, however one of skill in the art will appreciate that stent **4508** may also be deployed in a side branch of the vessel. The first catheter **4530** is a rapid exchange catheter (RX) having a guidewire lumen **4534** extending from the distal guidewire port **4538** at the distal end of the elongate shaft **4532** to a proximal guidewire port **4536** which is closer to the distal port **4538** than the proximal end of the catheter shaft **4532**. A connector **4544**, preferably a Luer connector is connected to the proximal end of the elongate shaft **4532** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **4532** for inflation of balloon **4540**. Having a portion of shaft **4532** disposed under proximal portion **4522** of stent **4508** helps keep catheter shafts **4504**, **4532** parallel and prevents tangling during delivery and as shaft **4532** is slidably advanced or retracted relative to shaft **4504**. Also, this ensures that a portion of balloon **4540** is also disposed under proximal portion **4522** of stent **4508**, and thus when balloon **4540** is inflated, the proximal portion **4522** of stent **4508** will be expanded while the distal portion **4514** will remain unexpanded. The first catheter **4530** may also be slidably advanced or retracted under the proximal portion **4522** of stent **4508** so that the shaft **4532** passes through the side hole **4520** in stent **4508**. Radiopaque markers may be placed at different locations on the shaft **4532**, often near the balloon **4540** or stent **4542**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **4502** includes an elongate shaft **4504** with a radially expandable balloon **4506** disposed near a distal end of the elongate shaft **4504**. A stent **4508** having a proximal portion **4522**, a distal portion **4514** and a side hole **4520** is disposed over the balloon **4506**. The distal portion **4514** is crimped to the balloon **4506** to prevent ejection during delivery, while the proximal portion **4522** is partially crimped to the balloon **4506** so the first catheter **4530** may be slidably advanced under the proximal portion **4522** of stent **4508**. The second catheter is an over-the-wire (OTW) catheter having a guidewire lumen **4512** extending from the distal guidewire port **4510** at the distal end of the elongate shaft **4504** to the proximal end of the elongate shaft **4504** into Y-adapter **4514** having a connector **4516**. The connector **4516** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **4512** exits via connector **4516**. A second connector **4518**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **4506** via an inflation lumen (not shown) in the elongate shaft **4504**. Radiopaque markers may be placed at different locations along the shaft **4504**, often near the balloon **4506** and/or stent **4508**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **41** illustrates another embodiment of a stent delivery system **4600**. The stent delivery system **4600** includes a first catheter **4602**, and a second catheter **4630**. The first catheter **4602** includes an elongate shaft **4604** with a radially expandable balloon **4606** disposed near a distal end of the elongate shaft **4604**. The proximal portion of balloon **4606** may be slidably advanced and retracted under stent **4642** via side hole **4620**. Thus inflation of balloon **4606** will also expand a proximal portion **4622** of stent **4642** while a distal portion **4614** of stent **4642** remains unexpanded. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **4612** extending from the distal guidewire port **4610** at the distal end of the elongate shaft **4604** to the proximal end of

the elongate shaft **4604** into Y-adapter **4614** having a connector **4616**. The connector **4616** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **4612** exits via connector **4616**. A second connector **4618**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **4606** via an inflation lumen (not shown) in the elongate shaft **4604**. Radiopaque markers may be placed at different locations along the shaft **4604**, often near the balloon **4606**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **4630** includes an elongate shaft **4632** with a radially expandable balloon **4640** disposed near a distal end of the elongate shaft **4632**. A stent **4642** having a proximal portion **4622**, a distal portion **4614**, and a side hole **4620** is disposed over balloon **4640**. The distal portion **4614** is crimped to balloon **4640** to prevent ejection during delivery, while the proximal portion **4622** is partially crimped to balloon **4640** so elongate shaft **4604** may be slidably advanced or retracted under the proximal portion **4622** of stent **4642**. The stent may preferably have a length that matches the working length of the balloon, or the stent length may be shorter than the balloon working length. At least a portion of balloon **4606** is distally offset relative to balloon **4640** and stent **4642** so as to minimize profile of the device. In this embodiment the stent **4642** is preferably deployed in a main branch of the vessel, although it could also be deployed in a side branch. The second catheter **4630** is a rapid exchange catheter (RX) having a guidewire lumen **4634** extending from the distal guidewire port **4638** at the distal end of the elongate shaft **4632** to a proximal guidewire port **4636** which is closer to the distal port **4638** than the proximal end of the catheter shaft **4632**. A connector **4644**, preferably a Luer connector is connected to the proximal end of the elongate shaft **4632** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **4632** for inflation of balloon **4640**. Having a portion of shaft **4604** disposed under proximal portion **4622** of stent **4608** helps keep catheters **4602**, **4632** parallel and prevents tangling during delivery and as shaft **4604** is slidably advanced or retracted relative to shaft **4632**. The first catheter **4602** may be slidably advanced or retracted under the proximal portion **4622** of stent **4642** so that the shaft **4604** passes through the side hole **4620** in stent **4642**. Radiopaque markers may be placed at different locations on the shaft **4632**, often near the balloon **4640** or stent **4642**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **42** illustrates another exemplary embodiment of a stent delivery system **4700**. The stent delivery system **4700** includes a first catheter **4730**, and a second catheter **4702**. The first catheter **4730** includes an elongate shaft **4732** with a radially expandable balloon **4740** disposed near a distal end of the elongate shaft **4732**. A proximal portion of the balloon **4740** may be slidably advanced or retracted through side hole **4720** and under proximal portion **4722** of stent **4708** as will be discussed below. This allows expansion of proximal portion **4722** of stent **4708** when balloon **4740** is expanded. At least a portion of balloon **4740** is distally offset relative to balloon **4706** and stent **4708** so as to minimize profile of the device. In this embodiment stent **4708** is preferably deployed in a main branch of the vessel, although it may be deployed in a side branch. The first catheter **4730** is a rapid exchange catheter (RX) having a guidewire lumen **4734** extending from the distal guidewire port **4738** at the distal end of the elongate shaft **4732** to a proximal guidewire port **4736** which is closer to the distal port **4738** than the proximal end of the catheter shaft **4732**. A connector **4744**, preferably a Luer connector is connected to the proximal end of the elongate shaft **4732** and allows an Indeflator or other device to be coupled with an inflation lumen (not shown) in elongate shaft **4732** for inflation of balloon **4740**. Having a portion of shaft **4732** disposed under proximal portion **4722** of stent **4708** helps keep catheters **4702**, **4732** parallel and prevents tangling during delivery and as shaft **4732** is slidably advanced or retracted relative to shaft **4704**. The first catheter **4730** may also be slidably advanced or retracted under the proximal portion **4722** of stent **4708** so that the shaft **4732** passes through the side hole **4720** in stent **4708**. Radiopaque markers may be placed at different locations on the shaft **4732**, often near the balloon **4740** or stent **4742**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **4702** includes an elongate shaft **4704** with a radially expandable balloon **4706** disposed near a distal end of the elongate shaft **4704**. A stent **4708** having a proximal portion **4722**, a distal portion **4714** and a side hole **4720** is disposed over the balloon **4706**. The distal portion **4714** is crimped to the balloon **4706** to prevent ejection during delivery, while the proximal portion **4722** is partially crimped to the balloon **4706** so the first catheter **4730** may be slidably advanced under the proximal portion **4722** of stent **4708**. The first catheter is a rapid exchange catheter (RX) having a guidewire lumen **4712** extending from the distal guidewire port **4710** at the distal end of the elongate shaft **4704** to a proximal guidewire port **4711** which is closer to the distal port **4710** than the proximal end of the catheter shaft **4704**. A connector **4716** is coupled with the proximal end of the elongate shaft **4704**. The connector **4716** is preferably a Luer connector and this allows easy coupling with an Indeflator or other device for inflation of the balloon **4706**. Radiopaque markers may be placed at different locations along the shaft **4704**, often near the balloon **4706** and/or stent **4708**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

FIG. **43** illustrates another embodiment of a stent delivery system **4800**. The stent delivery system **4800** includes a first catheter **4830**, and a second catheter **4802**. The first catheter **4830** includes an elongate shaft **4832** with a radially expandable balloon **4840** disposed near a distal end of the elongate shaft **4832**. A proximal portion of the balloon **4840** may be slidably advanced or retracted through side hole **4820** and under proximal portion **4822** of stent **4808** as will be discussed below. Thus, inflation of balloon **4840** will also expand the proximal portion **4822** of stent **4808**. At least a portion of balloon **4840** is distally offset relative to balloon **4806** and stent **4808** so as to minimize profile of the device. In this embodiment the stent **4808** is preferably deployed in the main branch of a vessel, although it may be deployed in a side branch. The first catheter **4830** is an over-the-wire (OTW) catheter having a guidewire lumen **4834** extending from the distal guidewire port **4838** at the distal end of the elongate shaft **4832** to the proximal end of the elongate shaft **4832** into Y-adapter **4846** having a connector **4848**. The connector **4848** is preferably a Luer connector and this

allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **4834** exits via connector **4848**. A second connector **4844**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **4840** via an inflation lumen (not shown) in the elongate shaft **4832**. Having a portion of shaft **4832** disposed under proximal portion **4822** of stent **4808** helps keep catheters **4802**, **4830** parallel and prevents tangling during delivery and as shaft **4832** is slidably advanced or retracted relative to shaft **4804**. The first catheter **4830** may also be slidably advanced or retracted under the proximal portion **4822** of stent **4808** so that the shaft **4832** passes through the side hole **4820** in stent **4808**. Radiopaque markers may be placed at different locations on the shaft **4832**, often near the balloon **4840**, to help mark the proximal and distal ends of the balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

The second catheter **4802** includes an elongate shaft **4804** with a radially expandable balloon **4806** disposed near a distal end of the elongate shaft **4804**. A stent **4808** having a proximal portion **4822**, a distal portion **4814** and a side hole **4820** is disposed over the balloon **4806**. The distal portion **4814** is crimped to the balloon **4806** to prevent ejection during delivery, while the proximal portion **4822** is partially crimped to the balloon **4806** so the second catheter **4830** may be slidably advanced under the proximal portion **4822** of stent **4808**. The first catheter is an over-the-wire (OTW) catheter having a guidewire lumen **4812** extending from the distal guidewire port **4810** at the distal end of the elongate shaft **4804** to the proximal end of the elongate shaft **4804** into Y-adapter **4814** having a connector **4816**. The connector **4816** is preferably a Luer connector and this allows easy coupling with a syringe or other device for lumen flushing or injecting contrast media. When unconnected, the guidewire lumen **4812** exits via connector **4816**. A second connector **4818**, also preferably a Luer connector allows attachment of an Indeflator or other device to the catheter for inflation of the balloon **4806** via an inflation lumen (not shown) in the elongate shaft **4804**. Radiopaque markers may be placed at different locations along the shaft **4804**, often near the balloon **4806** and/or stent **4808**, to help mark the proximal and distal ends of the stent or balloon, as well to facilitate alignment of the two catheters during stent deployment, as discussed elsewhere in this specification.

In any of the embodiments disclosed herein, commercially available catheters and commercially available stents may be matched up to form the systems illustrated. In still other embodiments, commercially available catheters that are single use devices for treating a single vessel may be mated together in various combinations and coupled together with a polymer sleeve. The operator chooses the two catheters for the patient's anatomy then slides a sized polymer sleeve over both catheters from the distal ends. Once the operator has the catheters aligned the polymer sleeve can be treated with a heat or light source to shrink and bond the two catheters together with friction. The polymer sleeve is made of typical polymers that can act as shrink wrap when treated with a heat or light source. The polymer of the polymer sleeve for example could be manufactured with polyolefin, a chemical used in manufacturing shrink wrap. The polymer sleeve would not crosslink or covalently attach to the catheters, several types of polymers are commercially available and have the requisite properties, thin, strong, not adhesive, and reaction times to their source of ten minutes or less. The polymer sleeves are typically 15 centimeters in length and have various diameters to suit typical catheter diameters 4 French to 20 French. The operator can test that the bond is holding by applying slight pressure prior to the procedure. If the polymer sleeve does not hold tightly the operator may elect to use a smaller diameter polymer sleeve or use more than one polymer sleeve by placing the polymer sleeves adjacent to each other. Alternatively, several smaller sleeves from 1 to 10 centimeters in length could be placed over several different portions of the catheters.

In any of the embodiments discussed herein, a therapeutic agent may be disposed on the stent or balloon and eluted therefrom in a controlled manner into the target treatment area such as a stenotic lesion. Exemplary therapeutic agents help inhibit restenosis, hyperplasia or have other therapeutic benefits. Exemplary anti-hyperplasia agents include anti-neoplastic drugs, such as paclitaxel, methotrexate, and batimastal; antibiotics such as doxycycline, tetracycline, rapamycin, everolimus, biolimus A9, novolimus, myolimus, zotarolimus, and other analogs and derivatives of rapamycin, and actinomycin; amino suppressants such as dexamethasone and methyl prednisolone; nitric oxide sources such as nitroprussides; estrogen; estradiols; and the like. Methods for applying the therapeutic agent to the stent or balloon are well known to those skilled in the art, and have been described in the patent and scientific literature.

Stent Delivery:

FIGS. **25**A-**30**B illustrate an exemplary delivery sequence of a preferred embodiment in eight steps. Step **1** illustrates the introduction of a 0.035 inch guidewire up to the bifurcation. Step **2** illustrates the tracking of a guide catheter over the guidewire. Step **3** illustrates the removal of the guidewire and placement position of the guide catheter. Step **4** illustrates the tracking and placement of a rapid exchange compatible wire in the daughter vessel and an over the wire compatible wire in the mother vessel. Step **5**A & **5**B illustrate tracking of the catheter system distally over both the guidewires. Step **6**A illustrates the inflation of the daughter balloon and placement of the daughter stent and partial deployment of the mother stent. Step **6**B illustrates the inflation of the mother balloon to place the distal portion of the mother stent in the mother vessel. Step **7**A illustrates mother stent in the main branch with side hole facing the daughter vessel. Step **7**B illustrates the bifurcated stent partially in the daughter vessel and daughter ostium completely opened and continuing on to the mother vessel.

In an alternative embodiment the delivery catheter mother balloons having tapered ends to accommodate balloons and stents with non-uniform profiles. For example, the proximal end of the daughter vessel stent may be designed to have a larger circumference than the distal end to compensate for the natural bifurcation anatomy. The daughter vessel balloon would likewise have a taper to properly expand the stent and ensure complete apposition. Additionally, it is possible to design the mother stent to expand differentially along its profile to compensate for a larger arterial diameter at the carina or ostium. In other words, the proximal and distal ends of the mother vessel balloon and mother vessel stent would be smaller in circumference while the center portion of the mother vessel stent would have a larger circumference. In an alternative embodiment the mother vessel balloon has tapered ends to accommodate the distal balloon catheter portion and guidewire lumen. Further, the mother vessel balloon may be designed for differential expansion to accommodate natural vessel anatomy.

In a preferred embodiment the distal (daughter) balloon catheter portion is crimped with a half stent on a rapid

exchange catheter. The daughter vessel stent is about 4-20 millimeters long and the daughter vessel balloon is approximately twice as long in length. The mother vessel stent is about 10-30 millimeters long, and is differentially crimped to allow independent operation of the daughter balloon catheter portion. The distal portion of the mother vessel stent is crimped tightly enough to keep the entire stent from unintentionally dislodging during the procedure. The proximal portion of the mother vessel stent is crimped just tightly enough to reduce the crossing profile and to allow the daughter balloon catheter portion to be moved distal or proximal relative to the mother balloon catheter portion. The proximal (mother) balloon catheter portion is an over the wire type design with the mother vessel balloon preferably about 3 centimeters proximal to the daughter vessel balloon. In an alternative embodiment a stent is designed to allow differential expansion of the middle portion of the stent relative to the proximal and distal ends. In particular, the design facilitates the placement of the stent across a bifurcation lesion in the mother vessel because it has a larger circumference in the middle portion relative to the ends than a stent with a constant profile. Further, the profile can be adjusted so that the largest circumference can be placed proximal or distal to the midpoint of the stent. In the particular embodiment the largest circumference is distal to the midpoint of the stent, but could be easily reversed for variable patient anatomy. Partial crimping has the following features that make it possible to maintain sufficient stent retention during delivery and placement and still allows the secondary system adjustability and deliverability.

FIG. **31** shows a partially crimped bifurcation stent prior to placement on any balloon catheter. FIG. **32-34** illustrate an embodiment of the present invention in three steps. First, the bifurcation stent is partially crimped over approximately one-third its distal portion onto the mother catheter balloon and the daughter catheter is loaded through the mother catheter and mother stent where the daughter stent can be crimped separately. Second, the daughter stent is crimped and pulled back proximally to align the daughter stent proximal end near the mother stent distal end. Third and final the proximal portion of the mother stent can be crimped to reduce the outer diameter; yet still allow independent movement of the two catheters relative to each other.

FIG. **35** illustrates a cross section of a mother and daughter balloon catheter system without a daughter stent. The daughter catheter is on top of the mother catheter. The mother stent is differentially crimped around the mother catheter balloon and daughter catheter because the daughter catheter profile is smaller than the mother catheter. The differential crimping is non-uniform and can create various cross sectional shapes to accommodate different catheter designs, balloon designs, and stent designs. For example, pear shaped or a figure eight are possible configurations. The current embodiment is designed to reduce the profile as much as possible. In one preferred method of manufacturing a protective sheet is placed between the two catheters. The protective sheet only needs to cover the portions that will come in contact during the crimping process, then the protective sheet can be removed.

FIG. **36** Illustrates a side view of the mother stent mounted on the mother catheter balloon and the daughter catheter mounted on the mother catheter through the mother stent. The distal portion of the mother stent will be crimped under standard conditions to hold stent firmly to the mother balloon and mother catheter. The proximal portion of the mother stent is the partially crimped to reduce the profile; but still allows the daughter catheter freedom to move proximal or distal relative to the mother catheter. This embodiment illustrates that the stent is differentially crimped in both the circumferential and longitudinal direction. The amount of crimping will be determined by the stent design and size, catheter dimensions, and balloon dimensions; thus the crimping is differential along the longitudinal axis.

FIG. **37** illustrates a side view of the mother stent mounted on the mother catheter balloon and the daughter catheter mounted on the mother catheter through the mother stent. The daughter catheter also includes a stent that can be crimped under standard conditions. The distal portion of the mother stent will be crimped under standard conditions to hold stent firmly to the mother balloon and mother catheter. In one experiment, this arrangement was tested to determine the strength of the distal crimping of the mother stent by pulling the daughter catheter and stent proximally; the results were that the daughter catheter successfully passed through the crimped mother stent and still retained the daughter stent as well. Additional features may be utilized during the crimping process such as adding a slight positive internal pressure to the balloon so that the final balloon surface pillows about 0.002 inch beyond the outer diameter of the stent. This process can yield a design that protects the stent from engaging with the vessel thus reducing friction and improving stent retention at the same time.

Further, this process improves safety and reduces trauma to the vessel. While the above embodiment discloses a bifurcation stent that is crimped at or about its distal half; this is not a limitation. The stent could be differentially crimped along its axis depending upon stent design, for example; if a hole in the side of a stent was not centered along the axis. It may be preferential to have the distal crimped portion of the bifurcation stent extend just distal of the hole that the daughter catheter to pass through. Alternatively, the distal crimped portion could extend partially or entirely over the hole that the daughter catheter passes through.

FIGS. **38**A-**38**M more clearly illustrate an exemplary method of provisionally treating a bifurcated vessel such as a bifurcated coronary artery. This method positions a stent in the main branch and provides side branch access. In FIG. **38**A the bifurcated vessel BV includes a side branch vessel SB and a main branch vessel MB. The main branch has a main branch lesion ML which may be disposed around the ostium to the side branch. The angle between the side branch and the main branch is referred to as the bifurcation angle, and is indicated by θ. In FIG. **38**B, a guidecatheter **3802** is advanced distally until its distal end is adjacent the bifurcation. A pair of guidewires GW**1**, GW**2** are then advanced from the guidecatheter **3802** distally toward the bifurcation such that the first guidewire GW**1** is advanced into the side branch SB and so that the distal tip of the first guidewire GW**1** is well past the ostium to the side branch. Similarly, the second guidewire GW**2** is also advanced distally in the main branch MB until the distal tip of the second guidewire GW**2** is distal of the main branch lesion ML. In FIG. **38**C, a stent delivery system having a first catheter **3804** and a second catheter **3824** are advanced distally from the guidecatheter **3802** toward the bifurcation. The first delivery catheter **3804** includes an elongate catheter shaft **3806** and a radially expandable balloon **3808** disposed over a distal portion of elongate shaft **3806**. The proximal portion **3810** of balloon **3808** may be retracted under a proximal portion of stent **3834** and thus when balloon **3808** is inflated, it will radially expand a proximal portion of stent **3834**, while a distal portion of stent **3834** will remain unexpanded. Proximal radiopaque marker **3812** and distal radiopaque marker

3816 help define proximal and distal ends of the balloon 3808. The radiopaque markers will also be used to help align the two catheters during treatment of the bifurcation, as will be discussed below. The distal tip 3818 may be a soft durometer polymer thereby minimizing trauma to the vessel during delivery. A distal guidewire port 3820 extends from the distal end of shaft 3806 and allows guidewire GW1 to exit or enter a guidewire lumen (not shown) in the elongate shaft 3806. The first catheter 3804 may be a rapid exchange catheter or an over-the-wire catheter, examples of which have been disclosed above. The second catheter 3824 (best seen in FIG. 38D) includes an elongate catheter shaft 3826 with a radially expandable balloon 3828 disposed over a distal region of the elongate shaft 3826. A stent 3834 having a side hole 3836 is disposed over the balloon 3828. The length of the stent 3834 may be substantially the same as the working length of the balloon 3828 or it may be less than the working length. In this exemplary embodiment, the stent 3834 has a length slightly shorter than the working length of the balloon 3828 thus a proximal portion 3830 and a distal portion 3838 remain unconstrained by the stent 3834. Proximal radiopaque marker 3832 and distal radiopaque marker 3840 help define the proximal and distal ends of the stent 3834 as well as the proximal and distal ends of the balloon 3828. The radiopaque markers will also be used to help align the two catheters during treatment of the bifurcation, as will be discussed below. The distal tip 3842 may be a soft durometer polymer thereby minimizing trauma to the vessel during delivery. A distal guidewire port 3844 extends from the distal end of shaft 3826 and allows guidewire GW2 to exit or enter a guidewire lumen (not shown) in the elongate shaft 3826. The second catheter 3824 may be a rapid exchange catheter or an over-the-wire catheter, examples of which have previously been disclosed above.

Referring back to FIG. 38C, the first catheter 3804 and the second catheter 3824 are further advanced distally so that the first catheter 3804 tracks over the first guidewire GW1 into the side branch SB while the second catheter 3824 tracks over the second guidewire GW2 in the main branch MB toward the main branch lesion ML. Because the first catheter 3804 is coupled with the second catheter 3824 via stent 3842, both catheters are advanced distally simultaneously thereby reducing procedure time, although this is not meant to be limiting, as each catheter may be advanced independently of the other. In this embodiment the first balloon 3808 is distal to the second balloon 3828 and stent 3834. This axial offset minimizes the system profile.

In FIG. 38D, both catheters 3804, 3824 are advanced further distally toward the bifurcation until the first balloon 3808 is positioned in the side branch, and the stent 3834 traverses the main branch lesion ML and the side hole 3836 is adjacent the ostium of the side branch SB. Advancement of both catheters 3804, 3824 is again performed simultaneously, although they could also be advanced independently of one another. The operator will feel resistance against further advancement of the catheters 3804, 3824 because as the catheters are advanced further distally, the two catheter shafts 3806, 3826 will spread apart relative to one another as they are forced against the carina of the bifurcation. However, a portion of the first elongate shaft 3806 is disposed under a proximal portion of stent 3834, therefore the two shafts 3806, 3826 can only spread apart so far. Thus, when an operator feels resistance against further advancement of the catheter shafts, the operator knows that both catheters 3804, 3824 and the associated stent and balloons are properly positioned relative to the bifurcation.

In FIG. 38E, the first catheter 3804 is retracted proximally relative to the second catheter 3824. Because a portion of the first catheter shaft 3806 is disposed under a proximal portion of the second stent 3834, the first shaft 3806 is slidably refracted into side hole 3836 and the first shaft 3806 and proximal portion 3810 of balloon 3808 are slidably retracted under a portion of stent 3834. The first shaft 3806 is proximally retracted until proximal radiopaque marker 3812 lines up with proximal radiopaque marker 3832. An operator may feel resistance during retraction of the first elongate shaft 3806 relative to the second elongate shaft 3826 as balloon 3808 slides under stent 3838. Stent 3834 has a distal portion crimped to balloon 3828 to prevent ejection during delivery, and a proximal portion is partially crimped thereto or uncrimped to allow catheter 3804 to slide thereunder. Crimping of the stent is disclosed in greater detail in other U.S. patents previously incorporated by reference above. The stent 3834 is disposed adjacent the main branch lesion ML and side hole 3836 is in rough alignment with the ostium to the side branch SB.

In FIG. 38F, the balloon 3808 is radially expanded, often with contrast medium, saline, or a combination thereof thereby radially expanding a proximal portion of stent 3834 into partial engagement with the main branch lesion ML and partially into engagement with the walls of the side branch near the ostium of the side branch SB. A distal portion of stent 3834 remains unexpanded.

In FIG. 38G the balloon 3808 is contracted, and then in FIG. 38H the other balloon 3828 is radially expanded, with contrast medium, saline, or a combination thereof, thereby further radially expanding the stent 3834. Expansion of balloon 3828 expands the proximal portion of the stent 3834 into engagement with the main branch vessel wall and main branch lesion ML, and the distal portion of the stent 3834 is also radially expanded into the main branch vessel wall distal to the bifurcation, as well as expanding the stent 3834 into the side branch walls near the ostium. The side hole 3836 is also further aligned with the ostium of the side branch SB.

Referring now to FIG. 38I, balloon 3828 is contracted and then both balloons are simultaneously inflated in a "kissing balloon" technique as seen in FIG. 38J. Both balloons 3808, 3828 are inflated with contrast medium, saline, or combinations thereof until they engage one another and are fully expanded in the main branch MB and side branch SB. The kissing balloon technique ensures that stent 3834 is fully expanded and in full apposition with the main branch and side branch walls and lesion. Additionally, the kissing balloon technique ensures that the side hole 3836 is lined up with the ostium of the side branch. Also, the kissing balloon technique ensures that the side hole does not block the ostium to the side branch thereby avoiding "stent jailing," or disrupting blood flow into the side branch.

In FIG. 38K, both balloons 3808, 3828 are contracted, and in FIG. 38L both catheters 3804, 3824 are retracted proximally. The catheters may be retracted simultaneously or independently of one another. The first catheter 3804 is retracted through side hole 3836 of stent 3834 and under a proximal portion thereof. The second catheter 3824 is retracted through the entire length of stent 3834. In FIG. 38M, both catheters 3804, 3828 have been removed, as well as the guidecatheter 3802 and both guidewires GW1, GW2. Stent 3834 remains implanted at the bifurcation. Optionally, the stent or any of the balloons may contain therapeutic agents such as those previously discussed, and these may elute out into the lesion at a controlled rate in order to help prevent restenosis.

The method illustrated in FIGS. **38**A-**38**M may use any of the delivery systems disclosed herein, but preferably uses those seen in FIGS. **40-43**. As discussed above, use of the devices in FIGS. **40-43** may also be "flipped" around in a method of ostial stenting wherein the stent is delivered partially in the main branch and partially in the side branch. Further details on this method are disclosed in U.S. patent applications previously incorporated herein by reference.

Any of the methods described above may use any of the stents disclosed herein in any of the system configurations described. Additionally, any of the features previously described above may also be used. Therefore, one of skill in the art will appreciate that any number of combinations may made. For example, catheter systems may have any combination of rapid exchange or over-the-wire configurations, with any of the stents disclosed herein, with or without a therapeutic agent on a balloon or a stent, and with or without any of the hollow exchange port, capture tube, removable capture tube, or snap fittings described above.

Stents:

The catheter systems and methods described above may use a commercially available stent for either the proximal or distal stent in the system. When a commercially available stent is used for the distal stent, it need only be crimped to the distal balloon catheter. When the commercially available stent is used for the proximal stent it may be partially crimped to the proximal balloon such that a portion of a second catheter shaft is slidably disposed under the stent and a portion of the second catheter shaft slidably passes through a side hole in the stent. The stent is crimped to the proximal balloon so that it is not displaced from the balloon during delivery, and also so the second catheter shaft can slide thereunder. FIGS. **39**A-**39**E illustrate several examples of commercially available stents that may be used in catheter system configurations and methods described above, either as is, or with slight modification. For example, FIG. **39**A illustrates the Abbott Vascular Xience® drug eluting stent **4102***a*. A portion of a catheter shaft may be disposed under the stent through its central channel and the catheter may exit a side hole in the stent. A side hole may be the gap **4104***a* created between adjacent struts in a cell, or the gap **4106***a* between axially adjacent cells. FIG. **39**B illustrates the Cordis Cypher® stent **4102***b*. Again a portion of a catheter shaft may be disposed under the stent through its central channel and the catheter may exit a side hole in the stent. A side hole may be the gap **4104***b* created between adjacent struts in a cell, or the gap **4106***b* between axially adjacent cells. FIG. **39**C illustrates the Boston Scientific Taxus® Liberté® stent **4102***c*. A portion of a catheter shaft may be disposed under the stent through its central channel and the catheter may exit a side hole in the stent. A side hole may be the gap **4104***c* created between adjacent struts in a cell, or the gap **4106***c* between axially adjacent cells. FIG. **39**D illustrates the Medtronic Endeavor® stent **4102***d*. A portion of a catheter shaft may be disposed under the stent through its central channel and the catheter may exit a side hole in the stent. A side hole may be the gap **4104***d* created between adjacent struts in a cell, or the gap **4106***d* between axially adjacent cells. FIG. **39**E illustrates a Palmaz-Schatz® stent **4104***e*. A portion of a catheter shaft may be disposed under the stent through its central channel and the catheter may exit a side hole in the stent. A side hole may be the gap **4104***e* created between adjacent struts in a cell, or the gap **4106***e* between axially adjacent segments. Other stents have been designed with side holes that are specifically intended to treat bifurcations. These stents may also be used with the systems and method disclosed herein. For example, FIGS. **39**F-**39**H illustrate several embodiments of stents from Boston Scientific and disclosed in detail in U.S. Pat. No. 7,678,142. FIG. **39**F shows a stent **4102***f* after it has been unrolled and flattened having a side hole **4106***f*. **39**F illustrates a stent geometry (unrolled, plan view) where the struts create a side hole **4106***f* that allows access to a side branch, and that can accommodate a catheter shaft as described herein. The side hole may be formed by the spaces **4104***f*, **4108***f* between struts. FIG. **39**G illustrates another stent geometry (unrolled, plan view) having a side hole **4106***g*. Alternatively, the side hole may be formed by the spaces **4104***g*, **4108***g* between struts or axial connectors. FIG. **39**H illustrates still another stent geometry (unrolled, plan view) having a side hole **4106***h*. The side hole may also be formed by the space between struts **4104***h* or axial connectors **4108***h*. In any of these embodiments, a catheter shaft may be slidably disposed under a portion of the stent, and the catheter shaft may exit the side hole. Additionally, any of the stents or balloons disclosed herein may carry a therapeutic agent such as those described above for local drug delivery. Also, while the stents disclosed herein are preferably balloon expandable, one of skill in the art will appreciate that self-expanding, and hybrid balloon expandable/self-expanding stents may also be used.

Balloon Configurations:

The balloons used to radially expand the stents described herein may be cylindrical balloons having a constant diameter along the working length, or diameter may vary. When stenting a tapered vessel, it may be advantageous to use a balloon which has a variable diameter balloon that more closely matches the vessel anatomy. For example, in FIG. **44**A, a tapered balloon **5006** is attached to the distal portion of shaft **5002**. A soft durometer tip **5004** prevents vessel trauma during delivery. The balloon is tapered such that a proximal portion **5010** of the balloon has a larger diameter than a distal portion **5006**. Any taper may be used. FIG. **44**B illustrates another embodiment of a balloon **5012** having a plurality of stepped regions **5014**. The stepped regions may be incremented in any amount, and in preferred embodiments, a proximal portion **5016** of the balloon has a larger diameter than a distal portion **5018**. Any of these embodiments, or combinations thereof may be used in the systems and methods described herein to treat a bifurcation. Use of a tapered or stepped balloon allows a stent to be expanded to more closely match the vessel walls, where a proximal portion of the expanded stent has a larger diameter than a distal portion of the stent.

In addition to using catheters having rapid exchange or over-the-wire guidewire lumens, and tapered or stepped balloons, the balloon catheters may not always employ a guidewire lumen. Instead, a fixed wire may be attached to a distal end of the catheter. For example, FIG. **45** illustrates an exemplary embodiment of a fixed wire catheter **5102** having a balloon **5106** attached to a distal portion of the shaft **5104**. A section of guidewire **5108** is fixedly attached to the distal end of the catheter and this fixed wire helps the catheter track through the vessels. The fixed wire may have any number of shapes including straight, curved, J-tip, etc. This embodiment may be used with any of the systems and methods disclosed herein, and it may or may not have a stent crimped to the balloon. The fixed wire catheter may be used in main branch, or more preferably it may be used in the side branch.

While the above is a complete description of the preferred embodiments of the invention, various alternatives, modifications, and equivalents may be used. Therefore, the above

description should not be taken as limiting the scope of the invention which is defined by the appended claims.

What is claimed is:

1. A system for treating a bifurcation, the system comprising:

a first delivery catheter comprising a first elongate shaft with proximal and distal ends, and a first expandable member adjacent the distal end of the first elongate shaft; and

a second delivery catheter comprising a second elongate shaft with proximal and distal ends, a second expandable member adjacent the distal end of the second elongate shaft, and a radially expandable stent disposed over the second expandable member,

wherein the stent comprises a sidewall having a side hole therethrough; and wherein the stent has a collapsed configuration suitable for delivery to the bifurcation, an expanded configuration in which the stent is configured to support a vessel, a proximal end, and a proximal portion extending along a proximal portion length from the proximal end to the side hole in the collapsed configuration; and

wherein a first portion of the first elongate shaft is disposed under the proximal portion of the stent, and the first elongate shaft passes through the side hole so that the first expandable member is disposed distal to the second expandable member for concurrent advancement of the first and second delivery catheters through the vessel, wherein the first elongate shaft is proximally retractable relative to the second elongate shaft while the stent is in the collapsed configuration to retract the first expandable member through the side hole into the proximal portion of the stent, and wherein the first expandable member includes a proximal working portion and a distal working portion distal to the proximal working portion, the proximal working portion having a length greater than the proximal portion length of the stent in the collapsed configuration, the distal working portion having a length sufficient so that the distal working portion extends into a branch of the bifurcation when a proximal end of the proximal working portion is positioned proximal to the proximal end of the stent in the collapsed configuration.

2. The system of claim **1**, wherein the first expandable member and the second expandable member are independently expandable of one another.

3. The system of claim **1**, wherein the first expandable member or the second expandable member comprise a balloon.

4. The system of claim **1**, wherein each of the first delivery catheter and the second delivery catheter comprise an inflation lumen.

5. The system of claim **1**, wherein each of the first delivery catheter and the second delivery catheter comprise a guidewire lumen.

6. The system of claim **5**, wherein the first delivery catheter comprises a distal guidewire opening in the distal end of the first elongate shaft, and a proximal guidewire opening, the proximal guidewire opening spaced closer to the distal guidewire opening than the proximal end of the first elongate shaft, and

wherein the guidewire lumen in the first delivery catheter is configured to slidably receive a guidewire, the guidewire lumen in the first delivery catheter extending from the distal guidewire opening to the proximal guidewire opening.

7. The system of claim **5**, wherein the second delivery catheter comprises a distal guidewire opening in the distal end of the second elongate shaft, and a proximal guidewire opening, the proximal guidewire opening spaced closer to the distal guidewire opening than the proximal end of the second elongate shaft, and

wherein the guidewire lumen in the second delivery catheter is configured to slidably receive a guidewire, the guidewire lumen in the second delivery catheter extending from the distal guidewire opening to the proximal guidewire opening.

8. The system of claim **5**, wherein the first delivery catheter comprises a distal guidewire opening in the distal end of the first elongate shaft, and a proximal guidewire opening in the proximal end of the first elongate shaft such that the proximal guidewire opening is closer to the proximal end of the first elongate shaft than the distal guidewire opening, and

wherein the guidewire lumen in the first delivery catheter is configured to slidably receive a guidewire, the guidewire lumen in the first delivery catheter extending from the distal guidewire opening to the proximal guidewire opening.

9. The system of claim **5**, wherein the second delivery catheter comprises a distal guidewire opening in the distal end of the second elongate shaft, and a proximal guidewire opening in the proximal end of the second elongate shaft such that the proximal guidewire opening is closer to the proximal end of the second elongate shaft than the distal guidewire opening, and

wherein the guidewire lumen in the second delivery catheter is configured to slidably receive a guidewire, the guidewire lumen in the second delivery catheter extending from the distal guidewire opening to the proximal guidewire opening.

10. The system of claim **1**, wherein the first expandable member has a cross-sectional profile smaller than a cross-sectional profile of the second expandable member.

11. The system of claim **1**, wherein one of the first elongate shaft or the second elongate shaft comprises a region having a guidewire lumen, an inflation lumen, and an exchange lumen,

wherein the other elongate shaft is slidably disposed in the exchange lumen, and

wherein the expandable member on the other elongate shaft is axially spaced apart from the elongate shaft having the exchange lumen such that the expandable member on the other shaft is distal to the expandable member on the elongate shaft with the exchange lumen.

12. The system of claim **1**, further comprising a capture tube having a proximal end, a distal end, a longitudinal axis, and a central channel extending between the capture tube proximal and distal ends, wherein the first elongate shaft and the second elongate shaft are slidably disposed in the central channel, and wherein the capture tube prevents the first elongate shaft from tangling with the second elongate shaft.

13. The system of claim **12**, wherein the capture tube comprises a perforated region extending along the longitudinal axis, the perforated region extending at least partially between the proximal and distal ends of the capture tube so that the capture tube may be peeled away from the first and second elongate shafts.

14. The system of claim **12**, wherein the capture tube comprises a locking mechanism for releasably holding the first elongate shaft and the second elongate shaft.

15. The system of claim **1**, wherein one of the first elongate shaft or the second elongate shaft comprises a snap

fitting configured to receive and retain the other elongate shaft, and wherein the other elongate shaft is slidably movable axially through the snap fitting, and wherein the expandable member on the other elongate shaft is axially spaced apart from the elongate shaft having the snap fitting such that the expandable member on the other elongate shaft is distal to the expandable member on the elongate shaft with the snap fitting.

16. The system of claim **1**, further comprising a polymer sleeve having a proximal end, a distal end, a longitudinal axis, and a central channel extending between the polymer sleeve proximal and distal ends, wherein the first elongate shaft and the second elongate shaft are slidably disposed in the central channel, and wherein the polymer sleeve prevents the first elongate shaft from tangling with the second elongate shaft.

17. The system of claim **1**, wherein the stent is balloon expandable.

18. The system of claim **1**, wherein the stent is non-uniformly crimped around the second expandable member and the first elongate shaft such that a first sector of the proximal portion is embedded into the second expandable member and a second sector of the proximal portion is not embedded into the first elongate shaft and has a smaller profile radius than the first sector, the first elongate shaft being proximally retractable relative to the second expandable member and the first stent in the crimped configuration to position the first expandable member within the proximal portion of the stent.

19. The system of claim **1**, further comprising a therapeutic agent disposed on the radially expandable stent, or disposed on one of the first or the second expandable members, the therapeutic agent adapted to being eluted therefrom.

20. The system of claim **19**, wherein the therapeutic agent comprises an anti-restenosis agent.

21. The system of claim **1**, wherein the first elongate shaft comprises a radiopaque marker disposed thereon, and wherein the second elongate shaft comprises a radiopaque marker disposed thereon, such that when the first radiopaque marker is aligned with the second radiopaque marker a working portion of the first expandable member is aligned with a working portion of the second expandable member.

22. The system of claim **21**, wherein the first expandable member or the second expandable member comprises a working length, the working length comprising a tapered region, wherein a proximal portion of the tapered region has a diameter larger than a distal portion of the tapered region.

23. The system of claim **1**, wherein either the first expandable member or the second expandable member is differentially expandable such that a proximal portion of the differentially expandable member has a larger diameter than a distal portion of the differentially expandable member.

24. The system of claim **1**, wherein the stent is differentially expandable such that in the expanded configuration a first portion of the stent has a larger diameter than a second portion of the stent.

25. The system of claim **1**, wherein the first delivery catheter comprises a first guidewire lumen extending at least partially between the proximal and distal ends of the first elongate shaft, the system further comprising a first guidewire, the first guidewire slidably positioned in the first guidewire lumen.

26. The system of claim **1**, wherein the second delivery catheter comprises a second guidewire lumen extending at least partially between the proximal and distal ends of the second elongate shaft, the system further comprising a second guidewire, the second guidewire slidably positioned in the second guidewire lumen.

27. The system of claim **1**, further comprising a guidewire fixedly attached to the distal end of either the first elongate shaft or the second elongate shaft.

28. The system of claim **1**, wherein the proximal portion of the stent, in the crimped configuration, has a figure eight cross-sectional shape or a pear shaped cross-sectional shape.

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